Program Overview

- The Team
- Goals & Approaches
- Challenges & Barriers
- R&D Strategy
- Budget
- Key Accomplishments
- 2017 Peer Review Response
- Future Directions
- Reviewers
The Team

Alison Goss Eng, Program Manager
Mark Elless Technology Manager
Art Wiselogel, AST Project Monitor

Chenlin Li M&O Contractor, INL
Luke Williams M&O Contractor, INL
Andrew Kobusch, AST Project Monitor

Owen Goldstrom, The Building People
Shaina Aguilar, ORISE Fellow
Bioenergy Technologies Office’s Critical Program Areas

Production & Harvesting

**Feedstock Supply**
Develops technologies to cost-effectively transform renewable carbon sources into high-quality, sustainable, and energy-dense feedstocks.

**Advanced Algal Systems**
Focuses on improving the productivity of algal biomass and enhancing the efficiency of cultivation and harvesting.

Conversion & Refining

**Conversion**
Develops technologies to convert non-food feedstocks into biofuels, bioproducts, and biopower.

**Advanced Development and Optimization**
Aims to reduce technology uncertainty in bioenergy by integrating individual technologies into a system/process and provides vital knowledge fed back to research programs.

Distribution & End Use

Crosscutting

**Sustainability and Strategic Analysis**
Supports program decision-making and develops science-based strategies to understand and enhance the economic and environmental benefits of advanced bioenergy.
Feedstock Supply & Logistics (FSL)

**Strategic Goal:** Develop science-based strategies and technologies to cost-effectively transform renewable carbon sources into high-quality, sustainable, and energy-dense feedstocks for biofuels, bioproducts, and biopower.

**Approaches:**
- Defining requirements and specifications for high-quality, conversion-ready intermediates
- Developing fundamental understanding of the interactions between feedstock properties and conversion performance
- Identifying the key feedstock quality and performance factors affecting biorefineries
- Improving the efficiency of feedstock logistics operations

Cost-effective, high-quality, sustainable, and energy-dense feedstocks
FSL Major Goals FY 2019–FY 2030

**By 2019**, identify the key feedstock quality and operation factors to achieve a modeled operational reliability of 45% for advanced feedstock-conversion systems that can sustainably supply corn stover and pine residues at a modeled delivered feedstock cost of $86/dry ton.

**By 2020**, identify key feedstock quality and operation factors to achieve a modeled operational reliability of 65% for advanced feedstock-conversion systems that can sustainably supply corn stover and pine residues at a modeled delivered feedstock cost of $86/dry ton.

**By 2022**, identify, characterize, and understand sources of variability in feedstock quality and energy content of renewable carbon feedstocks. Develop feedstock systems for these streams to deliver conversion-ready feedstock in support of the $86/dry ton goal.

**By 2030**, develop science-based strategies and technologies to cost-effectively transform renewable carbon sources into high-quality, sustainable, and energy-dense conversion-ready feedstocks at $71/dry ton.
Focus Areas

Strategies focus on improving the efficiency and reliability of harvesting/collection, storage, preprocessing, and transportation.

Improve the Quality and Quantity of Renewable Carbon Feedstocks

Reduce Cost of Renewable Carbon Feedstocks
Key Challenges and Barriers

Overcoming challenges and barriers are crucial to reaching program goals.

- Feedstock Availability and Cost
- Production
- Feedstock Genetics and Variety Improvement
- Sustainable Harvesting
- Feedstock Quality
- Biomass Storage Systems
- Biomass Physical State Alteration
- Material Handling and Transportation
- Feedstock Supply System Integration & Infrastructure
- Operational Reliability
Current Work Breakdown Structure

**Feedstock Supply & Logistics R&D**

- **Production & Supply**
  - Supply Chain Analysis
  - Biomass Production

- **Feedstock Logistics**
  - Harvest Collection & Storage
  - Transportation & Handling

- **Feedstock-Conversion Interface**
  - Feedstock Quality Improvement
  - Feed Handling Process Integration

- **Preprocessing**
R&D Strategy

Feedstock Supply & Logistics R&D

Production & Supply

Feedstock Logistics

Feedstock-Conversion Interface

“Standing-in-the field” to Harvest

Focus:
• Yield mapping
• Supply Curves
R&D Strategy

Feedstock Supply & Logistics R&D

Production & Supply

Feedstock Logistics

Feedstock-Conversion Interface

Harvest to Conversion
Focus:
- Harvest/Handling
- Collection
- Storage
- Transport
- Preprocessing
R&D Strategy

Feedstock Supply & Logistics R&D

Production & Supply

Feedstock Logistics

Feedstock-Conversion Interface

Feedstock Conversion Interface Consortium

Focus:
- Improved feed handling in biorefinery
- Biomass characterization for quality
- Transforming biomass to conversion-ready feedstock
Funding History

FSL Funding by Category ($Millions)

- **FSL**: $12, $15, $9
- **FCIC**: $4, $10, $8
- **FOA**: $8, $10, $9
- **Facility upgrades**: $5

FY17: $8, $12
FY18: $4, $10, $15
FY19: $5, $9, $8
R&D Strategy: Competitive & Lab Call Funding

- Advanced Biomass Feedstock Logistics Systems I
- Advanced Biomass Feedstock Logistics Systems II
- Landscape Design
- Feedstock Conversion Interface Consortia DFO
- Affordable and Sustainable Energy Crops
Key Accomplishments

Regional Feedstock Partnership
Completed project and produced summary report. Resulted in 134 peer-reviewed papers, 4 book chapters, 26 conference proceeding articles, and 48 extension/outreach publications

Biomass Research & Development
Two BRDI awards ($3M) will develop diverse, cost-effective cellulosic biomass technologies for use in biofuels and biobased products
Co-chair of two BR&D Interagency Working Groups

Affordable and Sustainable Energy Crops (ASEC) FOA
Three projects awarded ($15M), using new varieties/cultivars of energy crops leading to increased availability, cost-effectiveness, and environmental sustainability of energy crop production systems

Landscape Design for Sustainable Bioenergy Systems FOA
One project awarded ($9M), establish multi-disciplinary landscape design process, improve sustainability metrics, and assess logistics systems to deliver feedstocks to conversion facilities for bioenergy

Feedstock Conversion Interface Consortia (FCIC)
Established consortia. Awarded seven DFO projects ($8M)
Challenge: 7 out of 10 new pioneer biorefineries fail to achieve continuous profitable operations and only 3 out of 10 succeed.

Vision: Quantify, understand, and manage variability in biomass from field through downstream conversion and to understand how biomass composition, structure, and behavior impacts system performance

Provide First Principles based knowledge related to unit operations
Provide transfer functions to bridge scales from bench to pioneer biorefinery
Provide valuation of intermediate streams which can be commoditized

TOOLS FOR TECHNOLOGY DEVELOPERS AND BIOREFINERY DESIGNERS
Intra-agency Collaboration

- Engagement with Office of Science due to related R&D areas of interest Energy crops (BER), Sustainability (BER), Photosynthesis (BES)
  - BER Bioenergy Research Centers, particularly GLBRC (Great Lakes Bioenergy Research Center) with a thrust area in sustainability
- Engagement with ARPA-E through TERRA (Transportation Energy Resources from Renewable Agriculture) and ROOTS (Rhizosphere Observations Optimizing Terrestrial Sequestration)
  - Participate in review panels, connect through DOE Intra-agency quarterly meetings, also USDA REE engagement
Shockwave

Technology
• Innovative corn fractionation system. Separates biofuel feedstocks into distinct fractions

Approach
• Produce cellulosic fibers for biofuel and bio-product markets and demonstrate quality of cellulosic fiber
• Improve operational performance to optimize production of cellulosic-rich fiber fractions
• Evaluate the conversion potential of cellulosic fibers to cellulosic sugars and biofuels

Forest Concepts

Technology
• Innovative rotary-shearing comminution system

Approach
• This technology enables processing of high moisture and “wet bale” biomass to increase utilization of available biomass resources and reduce process wastes.
• Reduce the cost and improve the net energy balance of cellulosic biofuels and bioproducts
2017 FSL Peer Review

Key Recommendations:

✓ More effective collaboration with USDA,

✓ Increase emphasis on short to medium term feedstock and logistics issues, and

✓ Depot-level demonstration project
USDA Collaboration

• Three active Interagency working groups

• Goals for 2019 include:
  – Develop high-yielding regionally adaptive crops, and production and management strategies to enable large quantities of high-quality feedstock
  – Establish a fully developed biofuel and bioproducts production pipeline
  – Develop models and data of feedstock characteristics, equipment costs, crop investment, adoption risk, and policy to enable continuous improvement and adaptive management
## Short- to Medium-term Feedstock and Logistics Issues

<table>
<thead>
<tr>
<th>Densification</th>
<th>Storage</th>
<th>Supply Chain Risk</th>
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</thead>
<tbody>
<tr>
<td>• Solve particle attrition and fines generation during grinding</td>
<td>• Reduce storage related quality variations in delivered biomass</td>
<td>• Increased grower participation leads to reduced supply chain costs</td>
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<tr>
<td>• Enable pelleting as a viable option for conversion-ready cellulosic feedstocks</td>
<td>• Transform storage from a cost-center to a value-add operation</td>
<td>• Estimate risks and lower cost of capital of bioenergy projects</td>
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</tbody>
</table>

![Image of densified biomass](image1.png)

![Image of storage facility](image2.png)

![Graph showing perceived vs. actual feedstock risk](image3.png)
Future Directions: Carbon-Based Economy

The emerging bioeconomy utilizes diverse resources not traditionally FSL’s focus such as solid waste and industrial gases. FSL is partnering with other parts of BETO to frame our work in a new way and apply existing capabilities to new challenges.
Introductions – FSL Peer Review Panel

- Mr. Brandon Emme, ICM, Inc.
- Mr. Glenn Farris, AGCO (Lead Reviewer)
- Dr. Ray Miller, Michigan State University
- Dr. Dana Mitchell, USDA Forest Service – Southern Research Station
- Ms. Lynn Wright, WrightLink Consulting (formerly ORNL, University of Tennessee)

THANK YOU, REVIEWERS!
Thank you!

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Introductions – FCIC Peer Review Panel

• Dr. Lorenz (Larry) Bauer, Consultant (Lead Reviewer)
• Mr. Brandon Emme, ICM, Inc.
• Mr. Glenn Farris, AGCO
• Dr. Benjamin Levie, Formerly Weyerhaeser
• Andrea Slayton, Slayton Technical Services

THANK YOU, REVIEWERS!
<table>
<thead>
<tr>
<th>Project Name</th>
<th>ID#</th>
<th>Lead Org</th>
<th>Type of Org</th>
<th>Presenter</th>
<th>Award Type</th>
<th>Years</th>
<th>Funding</th>
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<tr>
<td>Feedstock Supply Chain Analysis</td>
<td>1.1.1.2</td>
<td>INL</td>
<td>Lab</td>
<td>David Thompson</td>
<td>AOP</td>
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<td>Supply Forecasts and Analysis</td>
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<td>Resource Mobilization</td>
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<td>Damon Hartley</td>
<td>AOP</td>
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<td>Development of a wet logistics system for bulk corn stover</td>
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<td>Lynn Wendt</td>
<td>AOP</td>
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<td>Size Reduction, Drying and Densification of High Moisture Biomass</td>
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<td>Jaya Tumuluru</td>
<td>AOP</td>
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<td>Lab</td>
<td>Rachel Emerson</td>
<td>AOP</td>
<td>2017-2021</td>
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<td>Sensors and Measurement in Harvest &amp; Collection for Rapid Quality Control of</td>
<td>1.2.1.1</td>
<td>INL</td>
<td>Lab</td>
<td>Bill Smith</td>
<td>AOP</td>
<td>2016-2021</td>
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<td>Corn Stover</td>
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<td>Demonstration of an Advanced Supply Chain for Lower Cost, Higher Quality</td>
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<td>FDC Enterprises</td>
<td>Industry</td>
<td>Kevin Comer</td>
<td>Logistics II FOA</td>
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<td>Biomass Feedstock Delivery</td>
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<td>Next Generation Logistics Systems for Delivering Optimal Biomass Feedstocks</td>
<td>1.2.3.107</td>
<td>University of Tennessee</td>
<td>University</td>
<td>Tim Rials</td>
<td>Logistics II FOA</td>
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<td>to Biorefining Industries in the Southeastern United States</td>
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<td>Improved Advanced Biomass Logistics Utilizing Woody and other Feedstocks in</td>
<td>1.2.3.108</td>
<td>The Research Foundation of SUNY/SUNY-ESF</td>
<td>University</td>
<td>Tim Volk</td>
<td>Logistics II FOA</td>
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<td>the Northeast and Pacific Northwest</td>
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<td>CEMAC: Evaluation of Agricultural Equipment Manufacturing for a Bio-based</td>
<td>6.3.0.8/9/10</td>
<td>NREL</td>
<td>Lab</td>
<td>Chad Augustine</td>
<td>AOP</td>
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<td>Economy</td>
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<td>Waste to Wisdom: Utilizing forest residues for the production of bioenergy and</td>
<td>3.4.1.4</td>
<td>Humboldt State University</td>
<td>University</td>
<td>Han-Sup Han</td>
<td>2012 BRDI FOA</td>
<td>2013-2017</td>
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<td>biobased products</td>
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FY19 FSL R&D Funding

FY19 + Forward Funding FSL = $31.58M

- FCIC AOP = $9.00M
- FCIC FOA = $5.00M
- FSL FOA = $3.80M
- FSL AOP = $6.23M
- Taxes = $2.55M
- PDU Upgrades = $5.00M
FSL Funding History (cont.)

FSL Enacted Budget ($Millions)

- FY17: $20
- FY18: $30
- FY19: $35
ASEC FOA Highlights

Areas of Focus:
• New varieties/cultivars of energy crops relative to predecessor varieties
• Regional adaptation
• Cost to produce
• Sustainability

Projects:
• Three projects selected; total federal share of $14.63M
• Next-Generation Feedstocks for the Emerging Bioeconomy (University of Illinois at Urbana-Champaign)
• Sustainable Herbaceous Energy Crop Production in the Southeast United States (Texas A&M AgriLife Research)
• Next Generation Miscanthus (North Carolina State Univ.)
Affordable and Sustainable Energy Crops (ASEC) FOA

On May 5th the U.S. Department of Energy (DOE) announced a FOA to support R&D related to the production of affordable and sustainable non-food dedicated energy crops that can be used as feedstocks for the production of biofuels and bioproducts.

Projects selected under this FOA will seek to:

- Conduct small-scale field testing of new varieties of energy crops
- Measure crop performance and environmental effects relative to traditional cropping and pasture systems
- Define cost-effective methods for planting, harvesting, collecting, and storing biomass

FOA Application Details:

- Funding Amount: Up to $15,000,000
  Funding Number: DE-FOA-0001917
- Letters of intent are due by May 30, 2018
- Full applications are due by June 27, 2018
FY18 FOA - Affordable and Sustainable Energy Crops (ASEC)

- **Goal:** Provide the scientific foundation and real-world data that enables industry to increase the availability, cost-effectiveness, and environmental sustainability of energy crop production.

- **Impact:** Increased sustainable supply of affordable, reliable, and resilient biomass feedstocks for conversion systems that produce advanced biofuels and performance-advantaged coproducts at less than $3/gge.

<table>
<thead>
<tr>
<th>TRL (start to end of projects)</th>
<th># of Awards</th>
<th>Federal $$ Per Award</th>
<th>Total Federal Funding</th>
<th>Award Duration</th>
<th>Cost Share (%)</th>
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<tbody>
<tr>
<td>4 to 5</td>
<td>3-6</td>
<td>$2.5-$5M</td>
<td>$15M</td>
<td>5 years</td>
<td>20%</td>
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R&D Challenges Addressed by ASEC FOA

- The United States has the technical potential to produce 240-380 million tons of energy crops annually by 2030, depending on yield-growth assumptions (DOE BT16 Report).
- Current cellulosic material is limited to agricultural and forestry residues.
- To achieve high volumes, energy crop production must be dependable, high-yielding, cost-effective, and environmentally sustainable.
  - To reduce biofuels to <$3/gge need to reduce delivered feedstock cost to < $84/ton. Research is needed to drive down production costs while increasing volumes of energy crops.
  - Empirical data are needed on the yields and environmental effects of newer varieties of energy crops associated with different geographic locations, soil types, and management practices (e.g., nutrient inputs) to drive sustainable productivity of affordable volumes of energy crops.

![Opportunity for Energy Crops in Inefficient Areas of Corn Fields](image.png)
New Goals and Structure (2019 onwards):

- Shift in approach from “quality by testing” to “quality by design”
  - Disciplined methodology employed by the pharma industry to manage variability in processes

- 5 “processing” tasks: (feedstock variability, materials handling, preprocessing, low-temp conversion, high-temp conversion)

- 3 Enabling tasks: (materials of construction, crosscutting analysis, data integration)
**Tasks Aligned With Operational Problem Areas**

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Preprocessing</th>
<th>Conversion</th>
<th>Characterization</th>
<th>Post processing</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Feedstock Variability:</strong> Develop tools that quantify &amp; understand sources of biomass feedstock variability with the objective of reducing sources of variability.</td>
<td><strong>Preprocessing:</strong> Develop tools to enable technologies that provide well defined, homogeneous, quality controlled feedstock.</td>
<td><strong>Conversion (HT and LT):</strong> Develop tools to enable technologies that produce homogeneous, quality controlled intermediates that can be converted into market ready products.</td>
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**Enabling Tasks**

- **Crosscutting Analyses TEA/LCA & Merit function Development:** Develops tools that enable valuation and intermediate streams and quantify impact of variability. Merit function develops tools that optimize on selected target globally.
- **Materials Handling:** Develop tools that enable continuous, steady, trouble free feed into reactors.
- **Materials of Construction:** Develop tools that specify materials that do not corrode, wear, or break at unacceptable rates.
- **Data Integration/Data Management & Validation:** Develop tools that can facilitate the transfer of data and information both internally and externally. Verify and vet tools developed in the other tasks via reliability models, iCorps, industrial engagement.