U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

# Overview of Feedstock Technologies Program

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# Agenda Overview


- The Team
- Reviewers
- Technology Area Strategy
  - Goals
  - Approach
  - Portfolio
  - Engagement
- Technology Area Progress
  - Active Management
  - Recent Successes
  - Future Plans

# The Feedstock Technologies "Family"

**Nichole Fitzgerald**
**Program Manager**

**Mark Elless**
**Technology Manager**

**Chenlin Li**
**Technology Manager**

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**Technology Manager**

**Art Wiselogel**
**ORISE Fellow**

Bri Farber
AAAS Fellow

**Clayton Rohman**
**Project Support**

**Alexander Jansen**
**Project Support**

**Richard Coaxum**
**Business Support**

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# Reviewer Introductions

- Mr. Glenn Farris, AGCO (*Lead Reviewer*)
- Dr. John Cundiff, Virginia Polytechnic Institute and State University (retired)
- Dr. Sally Krigstin, University of Toronto
- Mr. Jason Martin, Poet-DSM Project Liberty
- Dr. Dana Mitchell, USDA Forest Service – Southern Research Station
- Dr. Jingxin Wang, West Virginia University






**THANK YOU, REVIEWERS!**

# Program Goals

**Strategic Goal:** ***Develop science-based strategies and technologies to cost-effectively transform renewable carbon sources into high-quality, sustainable, conversion-ready, 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*

# FT Goals FY 2021–FY 2030

**By 2021**, deliver feedstocks meeting the defined critical material attributes (CMAs) for the 2022 verification, supporting a modeled minimum fuel selling price of $3/GGE and a 60% reduction in GHG emissions relative to petroleum-derived fuels.

**By 2022**, identify the preprocessing system and critical processing parameters necessary to deliver the required critical material attributes for biochemical and thermochemical conversion at 90% operating effectiveness that meet a delivered cost of $86/dry ton. reliability.

**By 2025**, verify coproduct technologies that utilize fractions of biomass derived from feedstock logistics and preprocessing to increase the total feedstock value by 10%.

**By 2030**, develop science-based strategies and technologies to cost-effectively transform carbon sources into sustainable, energy-dense, and conversion-ready feedstocks at 90% operating effectiveness that meet a delivered cost of $71/dry ton.

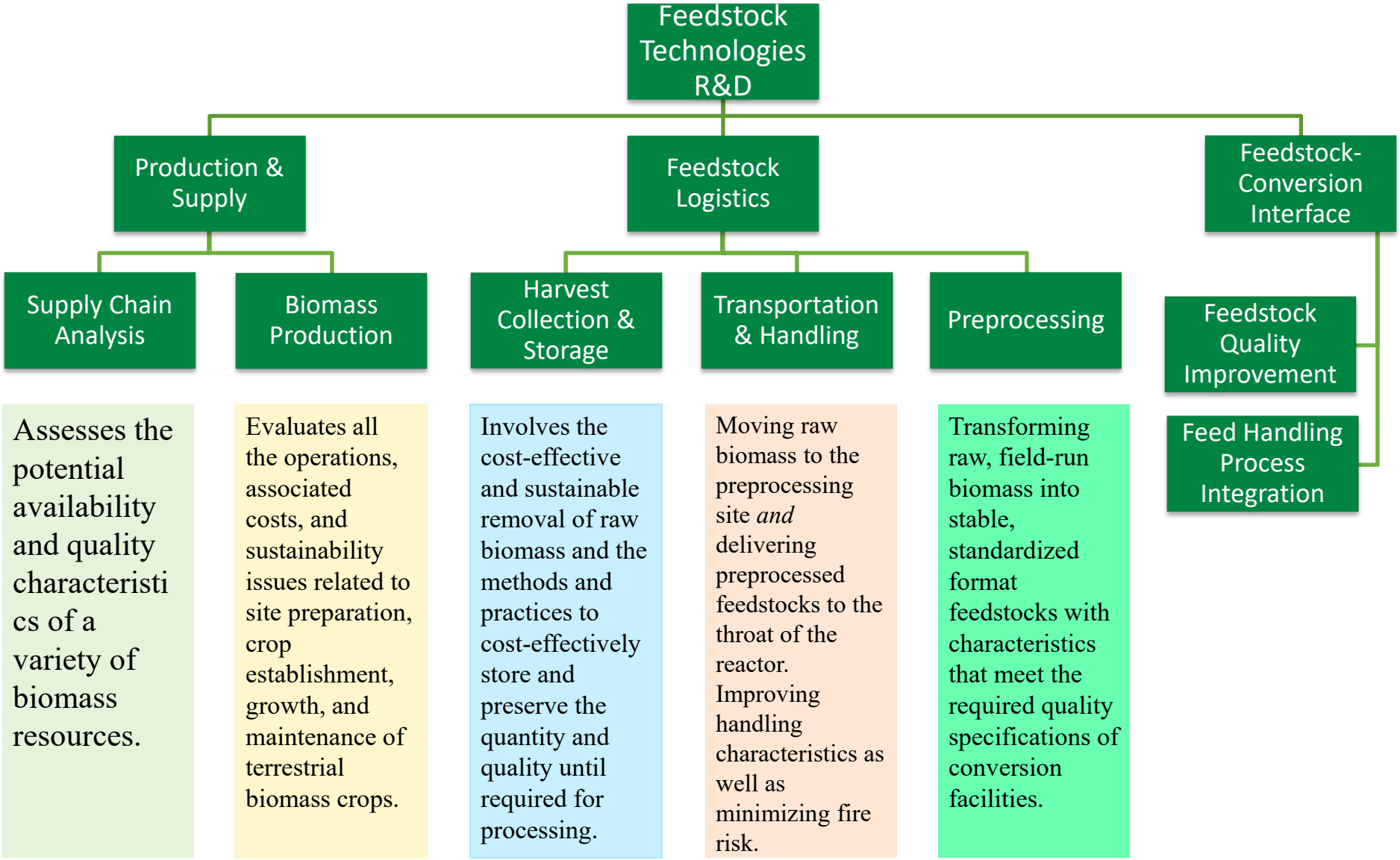



# Key Challenges and Barriers

The Feedstock Technologies program's challenges and barriers below highlight areas in which improvements 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

# Program Structure



# Key Funding Announcements

**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

**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

**Bio-Restore: Biomass to Restore Natural Resources FOA**

Three projects ($9M), will develop and employ new methods to quantify the environmental and economic benefits associated with growing energy crops on marginal and/or unproductive land with a focus on restoring water quality and soil health.

**Biomass Component Variability and Feedstock Conversion Interface FOA**

Seven projects ($8.6M), evaluate impact of biomass characteristics on feedstock performance in handling and conversion, design novel storage and handling approaches to control physical and chemical variability in biomass

**Advanced Fractionation and Decontamination of Municipal Solid Waste for Improved Conversion Efficiency FOA**

Four projects ($9M), develop advanced and techno-economically viable sorting and preprocessing methods tailored to MSW to address its known heterogeneity and variability, to produce high-purity, value-added feedstocks

# Advanced Biomass Feedstock Logistics Systems II FOA

**FOA Objective** - Developing and demonstrating strategies, equipment, and rapid analytical methods to manage feedstock quality within economic constraints throughout the feedstock supply chain

This FOA had two technical barriers and applicants had to address both:

- Technical Barrier #1: Feedstock Logsitics Cost - A target of $50/DT, or less, was set for all cumulative logistics costs (i.e., all costs incurred between harvesting the biomass through to the throat of the conversion reactor, including those associated with harvest, collection, preprocessing, and transportation and handling costs).
- Technical Barrier #2: Feedstock Quality - Successfully developing strategies and systems that ensure biorefinery in-feed requirements are reliably met year-round

| Federal $$ Per Award | Total Federal Funding | Award Duration | Cost Share (%) |
|---|---|---|---|
| $1.5 - $5M | $5.7M initially, $7.2M additional | 3 years | 20% |

# Affordable and Sustainable Energy Crops (ASEC) FOA

**FOA Objective** - To accelerate research and development related to the production of affordable and sustainable non-food energy crops that can be used as feedstocks for the production of price-competitive biofuels and bioproducts

This FOA also addresses a key research gap identified in the 2016 Billion Ton Report, Volume 2: Environmental Sustainability Effects of Select Scenarios from Volume 1, the need for empirical data gathered through field experiments on the yields and environmental effects of energy crops.

Successful projects will provide the scientific foundation and real-world data on new varieties/cultivars of energy crops that enables industry to increase the availability, cost-effectiveness, and environmental sustainability of energy crop production systems, leading to increased feedstock supply at decreased cost for conversion systems that produce advanced biofuels and coproducts.

| Federal $$ Per Award | Total Federal Funding | Award Duration | Cost Share (%) |
|---|---|---|---|
| $2.5 - $5M | $15M | 5 years | 20% |

# FY19 Multi-Topic FOA: Biomass Component Variability and Feedstock Conversion Interface Topic Area

Starting in FY19, BETO began running one office-wide FOA with Topic areas for each program within the office

**FT Topic Objective** - To investigate (a) the physical and chemical characteristics associated with individual tissue components of certain types of biomass (e.g., rind, pith, leaves, and cobs from corn stover; and needles, juvenile wood, and bark from southern pine forest residues), (b) how biomass characteristics change during storage, handling, and when undergoing preprocessing and conversion, and (c) the utilization of this knowledge to improve feedstock performance during preprocessing and conversion

All selections were made from the first sub-topic – (a) **Relating Biomass Physical and Chemical Characteristics to Feedstock Performance in Handling and Conversion Operations**

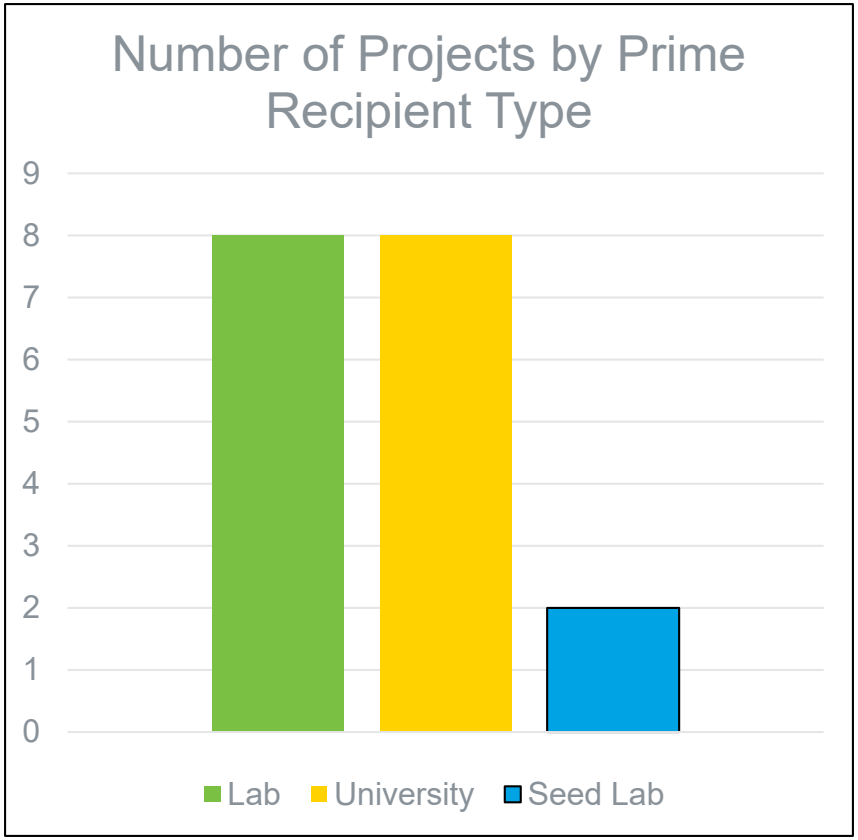
| Federal $$ Per Award | Total Federal Funding | Award Duration | Cost Share (%) |
|---|---|---|---|
| $600K - $3.5M | $8.6M | 3 years | 20% |

# Feedstock Conversion Interface Consortium

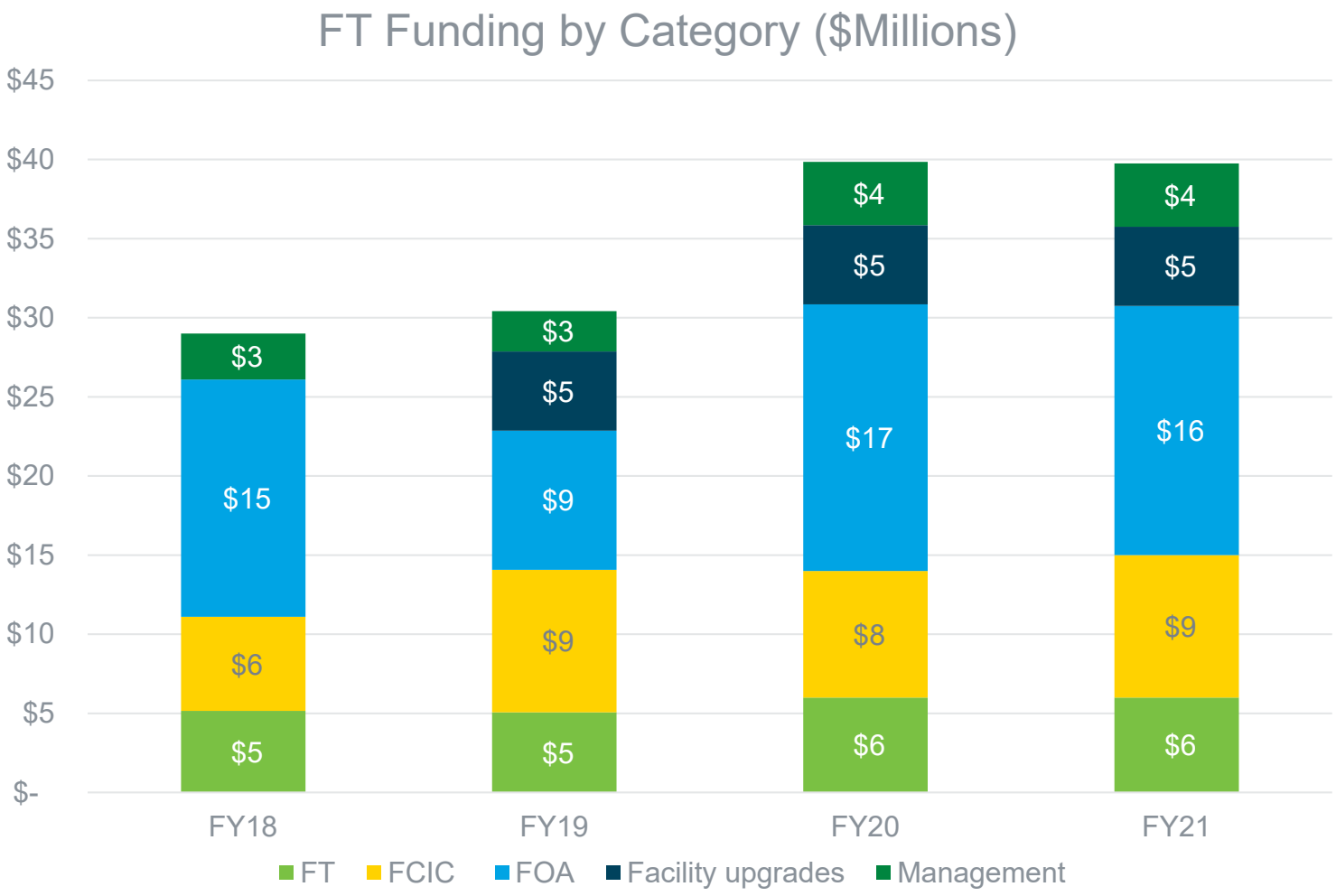
- Re-launched in FY19, focus on first-principles and Quality-by-Design approach to identify critical material attributes for each unit operation for efficient solids handling in biorefineries
- The FCIC is developing first-principles based knowledge and tools to understand and mitigate the effects of biomass feedstock and process variability on biorefineries

# FT Portfolio

- 18 Projects will be reviewed
  - Supply
  - Resource Assessment
  - Sustainability
  - Logistics
- 2 types of projects
  - National Laboratories
  - Competitive awards



# Budget



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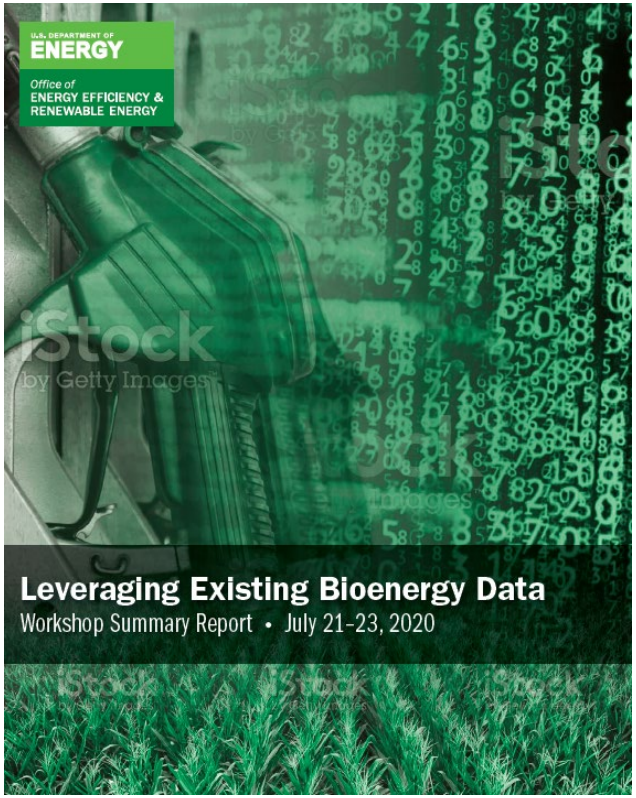
# Advancing the Bioeconomy: From Waste to Conversion-Ready Feedstock Feb 2020 Workshop

- **MSW stream is currently undervalued**
  - Combustion or landfill are two major pathways
- **Participants agreed that advancements in the following areas are necessary:**
  - Better fractionation technologies to separate MSW stream into distinct components
  - Characterization of MSW, across multiple scales and using rapid/real-time analysis techniques
  - Specifications for feedstocks for various conversion technologies
- **Benefits and drawbacks of AI also needs further exploration**
- **Robust environmental impact modelling of waste utilization is needed**
- **Non-technical recommendations included**
  - Consumer & industry education
  - Regulation (e.g. landfill bans, carbon tax/credits)

# Leveraging Existing Bioenergy Data Workshop July 2020

- **Goal: Discuss strategies for collecting and valorizing underused datasets and <u>associated knowledge</u>, with the objective of making this information public on existing databases**
- **189 total registrants**
- **Outcomes**
  - 49 existing, potentially acquirable datasets
  - More than 20 relevant established databases to house the bioenergy data
  - 31 data quality metrics with 94 suggested processes for confirming usefulness
  - 9 types of data owners and associated legal processes to acquire data
  - Multiple ideas for determining the monetary value of data
- **Report coming soon!**

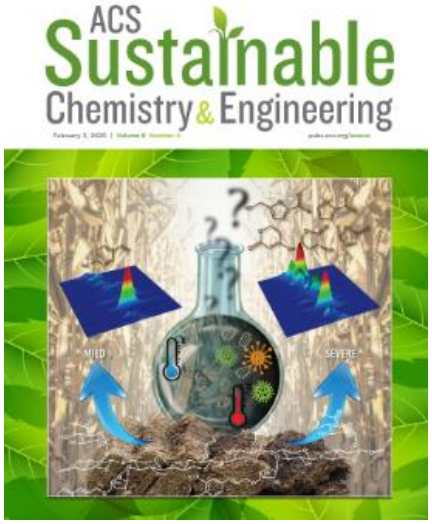


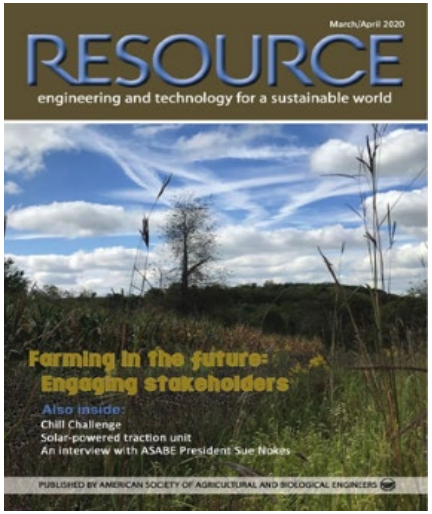
# Interagency Working Group (IWG)

- A collaborative effort that includes representatives from various agencies and programs within DOE, USDA, DOI, DOT, and the EPA. The group focuses on programs and activities that are addressing the challenges of improving biomass logistics systems, thus reducing the cost of biomass-derived feedstocks, fuels, and products.
- DOE and USDA are the leading agencies for logistics R&D, where logistics represents one part of a broader mission and wide range of goals and activities.
- The IWG mission is to advise, communicate, and coordinate federally funded R&D activities related to the logistics and transportation of terrestrial biomass feedstocks in an effort to reduce biomass logistics and transportation costs, improve biomass quality, and provide sufficient and on-spec feedstock to conversion process.

# Recent Successes

- FY20 Special Issue: ACS Sustainable Chemistry & Engineering, 3 were selected Journal Cover Art.
  - 4 papers in the Special Issues of "Recent Advances in Biomass Characterization and Modeling".
  - 8 papers in the Special Issue of "Impacts and Solutions to Biomass Variability at the Feedstock-Conversion Interface"
- 7 additional FCIC published papers, 1 under review
- FY20 Special Issue: Frontiers Research Topic: Storage of Biomass Feedstocks: Risks and Opportunities
  - Topic editors: Lynn Wendt, Vicki Thompson, Tim Volk (SUNY)
  - 7 INL manuscripts



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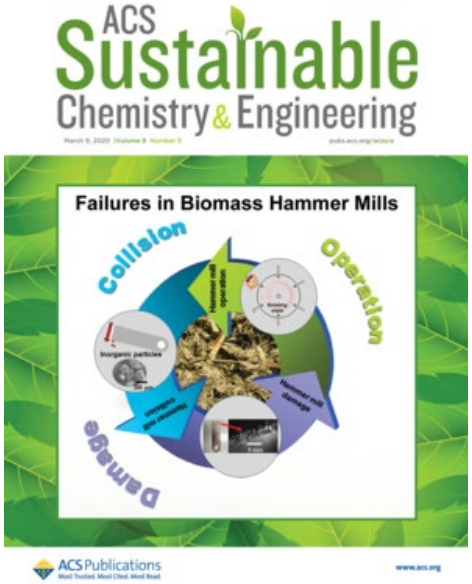
# Recent Successes

- FY19 Special Issue: Frontiers Research Topic: Advancement in Biomass Feedstock Preprocessing: Conversion Ready Feedstocks
  - Topic editors: Richard Hess, Allison Ray, Tim Rials (UT)
  - Finalist of 2019 Spotlight Award
- Regional Feedstock Partnership 2019 Workshop Report
- High moisture pelleting was an R&D Award Finalist in 2018 and 2020
- 2 patent applications submitted




R&D 100 AWARDS



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# Future Directions

- **Focus on Renewable Carbon Sources**
  - FT will expand its breadth of biomass materials beyond agricultural and forestry residues and energy crops into waste solids (e.g., MSW) and gases (e.g., CO2) for producing conversion-ready feedstocks
- **Lowering the price of delivered feedstock**
  - Using and blending “cost-advantaged” feedstocks
  - Developing co-products and new uses for off-spec material
- **Addressing MSW storage, handling, preprocessing, transportation logistics**

# Save the date! FY21 FT Workshop

- Virtual workshop
- Advancing Synergistic Waste Utilization as Biofuels Feedstocks: Preprocessing, Co-products, and Sustainability
- **April 14-15, 2021**; Online workshop registration will start in late February.
- Featuring the following topic areas:
  - MSW preprocessing technologies to address feedstock quality challenges and meet specifications for conversion pathways and downstream integration;
  - Opportunities of co-product development to utilize low quality MSW fractions for valorization;
  - Sustainability impacts of MSW utilization via the analysis of environmental, economic, and social factors.

# FY21 FOA Overview

- FOA Title:  FY21 Bioenergy Technologies Office Feedstock Technologies and Algae Funding Opportunity Announcement, DE-FOA-0002423
- Topic Area 1: Characterization of Municipal Solid Waste to Enable Production of Conversion-Ready Feedstocks
- Subtopic A: Measurement of variability of key MSW characteristics within and across unique MSW streams
  - Subtopic 1a focuses on understanding the variability of MSW characteristics that are critical to specific conversion technologies, to inform the steps necessary to produce conversion-ready feedstocks.
- Subtopic B: Development of novel methods for rapid/real-time measurements
  - Subtopic 1b focuses on developing rapid/real-time measurement techniques for critical characteristics.

# Additional Slides

# MYP Barriers

| | | |
|---|---|---|
| Ft-A | Feedstock Availability and Cost | Conversion technologies face a variety of technical, operational, and economic uncertainties. High-quality, affordable feedstock supplies are not consistently available, and supply and logistics systems can be unreliable due to a lack of fundamental understanding of properties and unique material handling challenges of many renewable carbon sources. Complete data on volumes, compositional variability, and characteristics by geographic location are needed to design and develop economical processes to deliver conversion-ready feedstocks. |
| Ft-B | Production | The production systems and performance of energy crop species are not well-characterized. The range of production-scale yields of energy crops across genetics, environments, and agronomic practices is not fundamentally understood and requires comprehensive characterization and reliable data from real-world production operations. Scientific information is lacking on new varieties/cultivars of energy crops, to inform the degree to which they show performance improvements relative to better characterized predecessor varieties, how well adapted they are across regions, whether they may be more cost-effective to produce, and whether they can be shown to be more sustainable relative to a control variety and/or traditional cropping/pasture systems. |
| Ft-C | Feedstock Genetics and Variety Improvement | The productivity and robustness of bioenergy crops is not optimized for bioenergy applications, and could be significantly increased by traditional breeding and selection and/or modern genetic engineering technologies. Reduced production uncertainty associated with more stress-tolerant varieties is needed to encourage farmers, biorefineries, and financial institutions to seriously consider energy crops. |
| Ft-D | Sustainable Harvesting | Current crop harvesting machinery is unable to selectively harvest or collect preferred components of renewable carbon sources to meet the capacity, efficiency, quality, or delivered requirements of biorefineries. Harvest, collection, sorting, and transport systems and equipment are not optimized for bioenergy applications. Logistics costs need to be reduced while improving biomass quality and processing efficiency. |
| Ft-E | Feedstock Quality | Monitoring and Impact on Preprocessing and Conversion Performance: The physical, chemical, microbiological, and post-harvest physiological variations in renewable carbon sources can be significant. For bioenergy crops, variability can arise from differences in genetics, relative crop maturity, agronomic practices and harvest methods employed, soil type, geographical location, and climatic patterns and events. Available data and information are extremely limited to identify the key physical (e.g., particle size, shape, pore volume, surface area, bulk density, and thermal conductivity), mechanical (e.g., compressibility, yield stress, shear, cohesion, friction, and rheological behavior), and chemical (e.g., moisture, ash content/speciation, carbohydrate, lignin content/speciation, extractives, and problematic contaminants) quality characteristics of feedstocks, and to understand the magnitude of their impacts on feeding, preprocessing, and conversion performance (e.g., throughput, yield, and equipment failure). Methods and instrumentation are also lacking for quickly, accurately, and economically measuring these quality-related properties. Analytical and processing standards, understanding of causal relationships and mechanisms at the molecular level, and quality specifications for bioenergy feedstocks are not well developed and may vary from one conversion process to another. |
| Ft-F | Biomass Storage Systems | Current storage systems (especially for wet, herbaceous materials and wastes) often result in degraded quality between the time of harvest or collection and use. This leads to storage-related physical and chemical degradation, poor feeding and handling performance, and periodic shutdown related to mill and conveyor plugging. The effect of different storage methods, and specifically moisture management, is not adequately defined to enable design of cost-effective systems that preserve quality and increase the stability of downstream operations. |
| Ft-G | Biomass Physical State Alteration | The initial sizing and grinding, cell wall structure, and particle characteristics of biomass affect conversion efficiencies and yields of all downstream conversion operations. To design technologies and equipment to economically process renewable carbon feedstocks to conversion specifications, information is needed on how the specific differences in the physical and mechanical properties of each feedstock at the nano- and micro-scale impact feed handling as well as conversion cost and yields. |
| Ft-H | Material Handling and Transportation | Raw herbaceous biomass and other renewable carbon sources have very low bulk and energy density, making transport costly. Conventional handling systems cannot cost-effectively deliver high volumes and are not optimized for bioenergy processes. |
| Ft-I | Feedstock Supply System Integration and Infrastructure | Conventional supply systems used to harvest, collect, store, preprocess, handle, and transport biomass are not designed to satisfy the large-scale needs of a nationwide system of integrated biorefineries. The infrastructure for feedstock logistics has not been defined for the potential variety of locations, climates, feedstocks, storage methods, and processing alternatives that will need to be implemented on a national scale. |
| Ft-J | Operational Reliability | Recent evidence indicates that biorefinery development and operation have suffered from failing to account for the complexity and variability of lignocellulosic biomass, inconsistent feeding and handling, inadequate equipment design, and flawed integration. To reach cost-effective operation, biorefineries need to operate at a design capacity of at least 90% on-stream reliability. Fundamental R&D is needed to identify the key feedstock quality and operation factors affecting operational reliability, develop technologies to address contributing factors, and develop process or operational strategies for mitigation. |

# MYP Milestones

| Milestone Title | Planned Year | Milestone Description |
|---|---|---|
| 20FS20 | 2020 | FT - By 2020, identify the differences among the macro-scale attributes of anatomical feedstock fractions and quantify the impact of the properties during primary deconstruction and handling to support the 2021 goal of delivering a feedstock that meets the CMAs for the 2022 verification. |
| 20FS22 | 2022 | FT - By 2022, identify the preprocessing system and critical processing parameters necessary to deliver the required critical material attributes for biochemical and thermochemical conversion, meeting a delivered cost of $86/dry ton and accounting for operational reliability. |
| 20FS23 | 2023 | FT - By 2023, identify CMAs for waste feedstock (e.g., MSW, plastics, and industrial wastes) for conversion at a modeled price of $86/dry ton. |
| 20FS24 | 2024 | FT - By 2024, develop feedstock supply systems (using mechanical, chemical, and thermal processing) for feedstock streams (e.g., energy crops, industrial wastes, plastics, and MSW) that produce the CMAs necessary for conversion at a modeled price of $84/dry ton. |
| 20FS25 | 2025 | FT - By 2025, verify coproduct technologies that utilize fractions of biomass derived from feedstock logistics and preprocessing to increase the total feedstock value by 10%. |
| 20FS30 | 2030 | FT - By 2030, develop science-based strategies and technologies to cost-effectively transform carbon sources into sustainable, energy-dense, and conversion-ready feedstocks that meet a delivered cost of $71/dry ton. |
| G20FS21 | 2021 | FT - By 2021, deliver feedstocks meeting the defined critical material attributes (CMAs) for the 2022 verification, supporting a modeled minimum fuel selling price of $3/GGE and a 60% reduction in GHG emissions relative to petroleum-derived fuels. |
| G20FS29 | 2029 | FT - By 2029, identify the key feedstock quality and variability factors necessary to produce conversion-ready feedstocks that meet a modeled delivered cost of $73/dry ton in support of a modeled minimum fuel selling price of $3/GGE and a 60% reduction in GHG emissions relative to currently predominant fuels. |