Bioenergy Feedstock Library Annual Summary Report

INL/RPT-24-81541
Revision 0

Energy and Environment Science & Technology

2024

OCTOBER 2024

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Battelle Energy Alliance manages INL for the U.S. Department of Energy's Office of Nuclear Energy

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EXECUTIVE SUMMARY

The Bioenergy Feedstock Library (BFL), part of the Biomass Feedstock National User Facility (BFNUF) located at Idaho National Laboratory (INL), is a physical sample repository and a web-accessible electronic database. The BFL stores physical and chemical characteristics of biomass and waste carbon sources for energy use, as well as samples generated from U.S. Department of Energy (DOE) Bioenergy Technologies Office (BETO) and U.S. Department of Agriculture-funded projects. The objective of this Bioenergy Feedstock Library Annual Summary Report for 2024, similar to the 2023 Annual Summary Report[1], is to focus on the updates to: (1) publicly available analytical data and equipment tracked through the BFNUF, (2) significant increases in the physical samples available for request, (3) sample and data archival progress from recent BETO-funded projects, and (4) publicly available data sets created upon request from BETO, INL projects, or outside entities compared to the previous annual summary reports. This report highlights key statistics and available data and information important for INL, BFL users, academics, and industry.

Some key highlights from this report include the following:

- The BFL currently tracks over 115,000 unique samples, each with its own barcode. Over 69,000 of these samples and associated data have been made publicly available.
- The BFL hosts over 200 unique feedstock types representing agricultural and forest resources, energy crops, wastes, and algae. Within these feedstock categories, over 900 unique subtypes (e.g., cultivars, representations of municipal solid fractions) are available.
- Over 31,000 samples have analytical data in the BFL. The largest analytical data categories represented for the publicly available samples are moisture, fuel properties (i.e., volatiles, fixed carbon, ash, carbon, hydrogen, nitrogen, oxygen, sulfur, and calorimetry), and compositional characterization (e.g., carbohydrate, lignin, ash, extractives, and protein contents), accounting for 79% of the available analytical data.
- Of the publicly available samples, there are over 70 unit operations tracked in the BFL spanning the biomass supply chain and nearly 26,000 samples representing fractionation, separation, and splitting-type unit operations.
- The BFL freely provides physical samples to researchers along with any available relevant analytical data, including bulk reference materials and over 4,000 physical samples generated from the Regional Feedstock Partnership (RFP) and Feedstock Conversion Interface Consortium (FCIC).[2]

[1] Emerson, Rachel M., et al. Bioenergy Feedstock Library 2023 Annual Summary Report. United States. https://doi.org/10.2172/2204843

[2] Office of Energy Efficiency and Renewable Energy. n.d. "Feedstock-Conversion Interface Consortium." Bioenergy Technologies Office. Last modified 2023. https://www.energy.gov/eere/bioenergy/feedstock-conversion-interface-consortium.

- More than 2,400 samples generated through BETO's various Funding Opportunity Announcement projects have been archived in the BFL, representing purpose-grown energy crops and municipal solid waste resources.
- The BFL currently provides 17 data sets containing sample and data summaries from peer-reviewed publications, RFP field studies, and data sets generated in response to BFL user data requests that may be of interest to other researchers.

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CONTENTS

FIGURES

TABLES

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ACRONYMS

ASEC	Affordable and Sustainable Energy Crops
BETO	Bioenergy Technologies Office
BFL	Bioenergy Feedstock Library
BFNUF	Biomass Feedstock National User Facility
C&D	Construction and demolition
CRP	Conservation Reserve Program
DOE	Department of Energy
FCIC	Feedstock Conversion Interface Consortium
FOA	Funding Opportunity Announcement
INL	Idaho National Laboratory
MRF	Material Recovery Facility
MSW	Municipal solid waste
NIR	Near-Infrared
RFP	Regional Feedstock Partnership
RBRH	Regional Biomass Resource Hub Initiative
RACIPAC	Reducing Agricultural Carbon Intensity and Protecting Algal Crops

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Bioenergy Feedstock Library Annual Summary Report

2024

1. Introduction

The Bioenergy Feedstock Library (BFL), part of the Biomass Feedstock National User Facility (BFNUF)[3] located at INL, is a physical sample repository and a web-accessible electronic database. The BFL stores physical and chemical characteristics of biomass and waste carbon sources for energy use, as well as samples generated from U.S. Department of Energy (DOE) Bioenergy Technologies Office (BETO) funded projects (BFL About Us).

The BFL offers a sample and data management system to support bioenergy researchers in managing active projects. Upon project completion, the data and samples can be made public, contributing to a comprehensive catalog. This catalog provides researchers and industry with access to physical samples and data, helping them understand and address the variability in the physical and chemical properties of biomass. Additionally, it offers all stakeholders accessible information on a wide variety of bioenergy feedstock materials. The BFL has been a publicly available resource supported by BETO since 2015.

1.1. Summary Report Objective

The objective of this 2024 Bioenergy Feedstock Library Annual Summary Report is to provide updated information from the 2022 and 2024 Annual Summary Reports and focus on the (1) publicly available analytical data and equipment tracked through the BFNUF, (2) significant increases in the physical samples available for request, (3) sample and data archival progress from recent BETO-funded projects, and (4) publicly available data sets created upon request from BETO, INL projects, or outside entities compared to the previous annual summary reports. This report highlights key statistics and available data and information important for INL, BFL users, academics, and industry. This report in not intended to capture all information available within the BFL, but instead give current BFL users and potential users an insight into the type of information available. Researchers are encouraged to contact the BFL with further inquiries regarding specific information (biomasslib@inl.gov).

2. Bioenergy Feedstock Library Overview and Users

The diverse feedstock resources represented in the BFL reflect the evolving bioenergy research priorities of BETO-funded projects over the past decade. The BFL is a living database and serves as the primary sample and data management system for nearly 200 past and present bioenergy-focused projects. This has resulted in the management of sample information and data for more than 115,000 bioenergy samples, with approximately 3,000 to 5,000 new samples created each year. Using the BFL database, the data and samples from these projects can easily be made publicly available as projects are completed. To date, information for over 69,000 samples has been made publicly accessible, compared to FY 2022, when approximately

[3] Biomass Feedstock National User Facility. https://inl.gov/bfnuf/

52,000 samples and data were publicly accessible. One of the goals of the BFL is to continue increasing data and sample accessibility as projects conclude. The BFL provides aggregated data and information for public samples through a public-facing web portal without requiring a login. The BFL also allows users to create accounts to access and export more data and sample-specific information. To register for an account, visit the Registration page. Currently, the BFL has approximately 428 active registered users spanning government, industry, and academic institutions in the U.S. and internationally (Figure 1). In FY 2024, the BFL saw a significant increase in user registration, registering 57 new users, with 49% of the newly registered users representing industry groups.

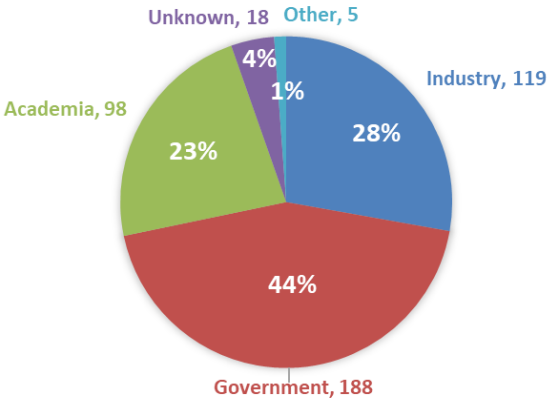


Figure 1. Summary of active users represented in the Bioenergy Feedstock Library.

3. Biomass and Feedstock Overview

The BFL houses information for over 200 unique feedstock types spanning agricultural, forest, waste, and algae resource types, as well as blends of multiple resource types (Figure 2).[4] Over 30 feedstock types have been added to the BFL since 2022, representing various waste resources, including fractions of municipal solid waste and residuals from material recovery facilities (MRFs). Over 9,000 samples are currently being tracked for these newly added feedstocks.

Approximately 90% of the publicly available samples in the BFL comprise herbaceous energy crops (e.g., energy cane), agricultural residues (e.g., corn stover), and softwood trees representing forest resources from forest thinning or logging operations (e.g., pine). Between fiscal year (FY) 2022 and FY 2024, the number of publicly available agricultural

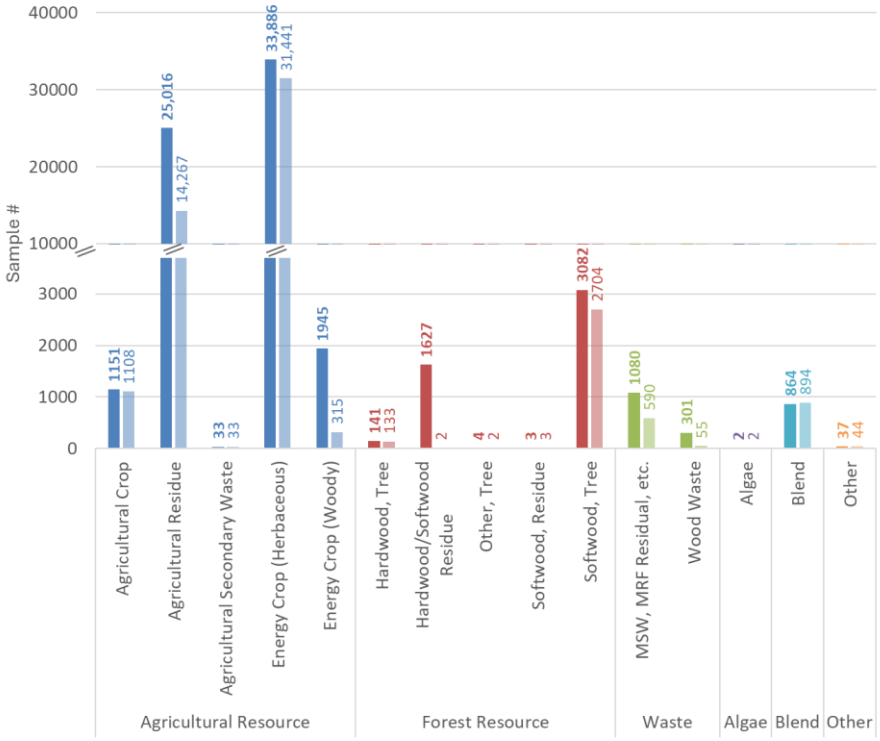


Figure 2. Number of samples for feedstock resource categories publicly available in FY 2024 (darker) compared to FY 2022 (lighter).

[4] The difference between the "trees" and the "residues" in Figure 2 under Forest Resources is the tree typically represents the white wood or whole tree resources while the "residues" typically represent the residue fractions of the tree after logging or thinning. However, these whole tree resources are used to understand variability in logging and thinning operations.

residue samples increased the most compared to other feedstock types, rising from 14,267 to 25,016, a 75% increase. The number of publicly available waste resources, representing materials from landfills and recovery facilities, also saw significant increases, rising from 590 to 1,080, an 83% increase.

In addition to the more than 200 feedstock types, the BFL has over 900 unique subtypes. These subtypes represent cultivars, varieties, species, and other differentiating factors for multiple feedstock types. These feedstock subtype details are captured in metadata fields, such as cultivar, genotype, and species, that are tracked in the BFL. Table 1 provides a summary of some of the biomass subtypes represented for various publicly available biomass resources. Barley straw and wheat straw samples have some of the largest genetic variability currently in the BFL from BETO-funded projects dating back to the early 2000s. Barley straw has 69 unique cultivars/varieties represented among 247 samples, while wheat straw has 182 cultivars/varieties represented among 2,624 samples. Materials like municipal solid waste (MSW) paper fractions, construction and demolition (C&D) waste, or wastes that might be found in C&D waste streams, are also represented in the BFL through subcategorization metadata to differentiate these unique waste types. The number of publicly available waste sample types from MSW represented in FY 2022 has increased to 1,381, including those listed in Table 1. With the BFL's role in sample archival for waste resources, including MSW under BETO-funded projects for the FY 2021 BETO Feedstocks FOA Topic Area 1[5] and FY 2022 BETO Feedstocks FOA Topic Area 1,[6] it is anticipated that publicly available samples and data from these feedstock types will significantly increase in the coming years.

Table 1. Summary of feedstock subtypes, including cultivars represented in the BFL for publicly available samples.

Feedstock Types	Subtypes	Sample Number[a]
MSW Paper/Fiber Fraction	8 types (e.g., corrugated cardboard, glossy paper, newspaper, mixed paper resources)	57
Construction and Demolition (C&D) or other similar waste types	16 unique types (i.e., 5 types of lumber, wafter board, oriented strand board, 2 joist types, particle board, MDF, plywood)	301
Barley Straw	69 unique cultivar/varieties (e.g., Baretta, Cochise, Drummond)	247
Corn Stover/Cob/Stalk/Grain	23 cultivars represented (e.g., DeKalb 61-69, Legend LR9779RR, Pioneer P0461xr)	22,027
Energycane	11 cultivars (e.g., Ho 06-9001, L 99-233, Ho 72-114)	842
Grass Clippings/Mixed Lawn Grasses	5 genera (i.e., Cynodon, Poa, Lolium, Festuca, and Zoysia) 4 species (i.e., Bermuda, Kentucky Bluegrass, Ryegrass, Tall Fescue)	326
Hybrid Poplar	2 cultivars (i.e., P. deltoides × P. maximowiczii, P. deltoides × P. nigra hybrid)	308
Mixed Grasses	10 species[b] (e.g., tall fescue, orchardgrass, little bluestem)	5,657
Shrub Willow	35 cultivars (e.g., Onondaga, Fishcreek, 00X-026-082)	1,606
Sorghum	3 types (i.e., forage, biomass, sweet) ~14 cultivars (e.g., ES5200, M81E, SugarT)	5,478

[5] Office of Energy Efficiency and Renewable Energy. 2021. "Department of Energy Announces Nearly $34 Million to Advance Waste and Algae Bioenergy Technology." Bioenergy Technologies Office. Last modified July 31, 2020. https://www.energy.gov/eere/bioenergy/articles/department-energy-announces-nearly-34-million-advance-waste-and-algae

[6] Office of Energy Efficiency and Renewable Energy. 2022. "Department of Energy Announces $29.5 Million for Improved Bioenergy Resource Recovery and Conversion Systems." Bioenergy Technologies Office. Last modified August 31, 2022. https://www.energy.gov/eere/bioenergy/articles/department-energy-announces-295-million-improved-bioenergy-resource.

Feedstock Types	Subtypes	Sample Number[a]
Switchgrass	6 cultivars (i.e., Alamo, Blackwell, Cave-in-rock, Kanlow, Southlow, Sunburst)	17,417
Wheat/Wheat Straw	182 cultivars/varieties (e.g., Amidon, Briggs, Alturas)	2,624

[a] Sample numbers may decrease between reports due to recategorization or representation of the available data.
[b] Mixed grass samples have composition of species reported within each sample in many cases.

4. Analytical and Operational Data

One of the key features of the BFL is the critical analytical data it provides for the large portfolio of bioenergy resources available. The BFL tracks analytical data for over 31,000 samples, of which over 22,000 have been made publicly available. An additional 5,000 samples with analytical data have been made available since the FY 2022 Annual Summary Report was released. The analytical data housed in the BFL are grouped into analysis type categories, as shown in Figure 3. Currently, 79% of the available data in these analysis type categories is accounted for by moisture analysis, fuel properties characterization (e.g., volatiles, ash, fixed carbon, total carbon, hydrogen, nitrogen, oxygen, sulfur, and calorific values), and compositional characterization (e.g., carbohydrate, lignin, ash, extractives, and protein contents). These properties represent key attributes impacting biochemical and thermochemical conversion pathways to biofuel production for these feedstocks. Over 4,500 samples with these chemical characteristics have been made publicly available since the release of the FY 2022 Annual Summary Report.

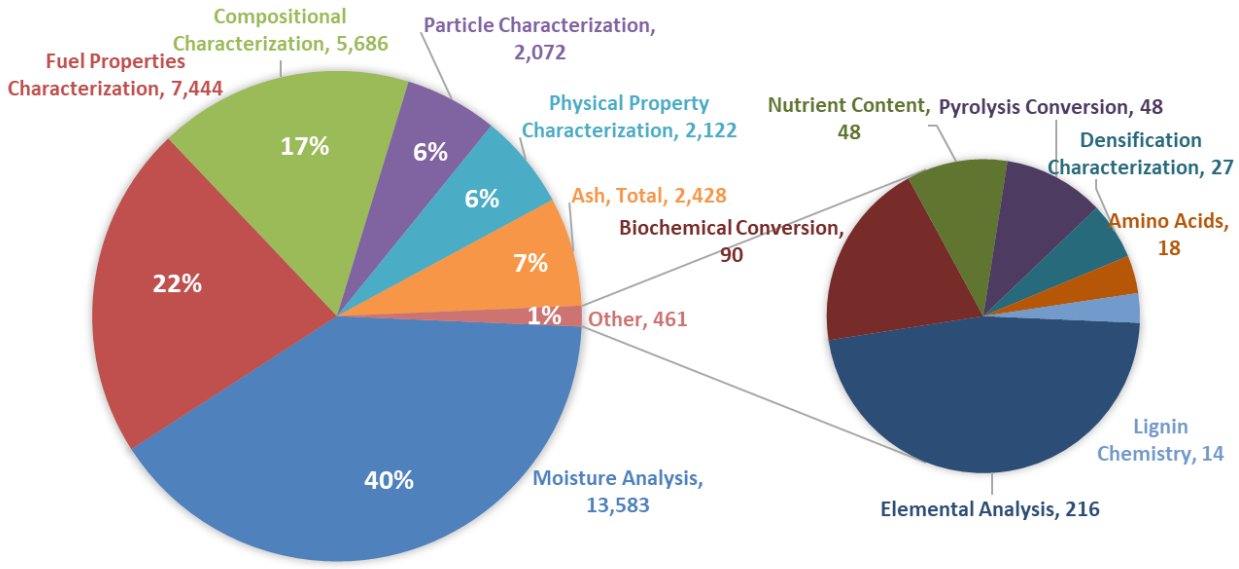


Figure 3. Publicly available analytical data in the BFL.

Another important factor to note about the analytical data tracked in the BFL is that provenance information regarding methods, institutions, and quality control/quality assurance is associated with the analytical data points where available as part of the BFL's data quality approach. For example, the compositional characterization data shown in Figure 3 is made up of analyses representing four different methods: (1) a wet chemistry method performed by INL staff following the National Renewable Energy Laboratory

(NREL) Laboratory Analytical Procedures (LAP) for compositional analysis of biomass,[7] (2) prediction values from a near-infrared (NIR) model built by NREL based on the NREL compositional analysis of biomass LAPs[8] (3) prediction values from an NIR model built by South Dakota State University based on a detergent fiber method for compositional characterization of biomass,[9] and (4) a high-resolution thermogravimetric analysis model for predicting cellulose, hemicellulose, and lignin concentrations built by the State University of New York College of Environmental Science and Forestry.[10] Each of the analytical values from these methods is tracked separately to retain data integrity in the BFL. More information on analytical data collected by INL specifically and tracked in the BFL can be found through INL's Bioenergy Feedstock Characterization Laboratory (Bioenergy Feedstock Characterization Laboratory).

Along with the analytical data, another unique and important feature of the BFL is its ability to track relationships between samples that are represented by unit operations. As material is handled or changes form, chemically or physically, via a unit operation, new samples are created in the BFL to represent the newly formed child sample. This hierarchical tracking using globally unique identifiers (GUIDs) allows for the capture of information specific to each step in a process. This information includes specifics about equipment and processing parameters along with the analytical data accompanying these child and parent samples. There are approximately 70 unique unit operations tracked in the BFL, spanning feedstock supply and logistics, preprocessing, and conversion process areas. Figure 4 shows the number of publicly available samples for some of the key categories of unit operations. Currently, samples with the highest representation in the BFL are those that have undergone preprocessing unit operations of size reduction through a variety of mills and grinders as well as fractionation using equipment such as air classifiers and screens. The number of samples available for these preprocessing categories compared to the FY 2022 Annual Report has increased from 14,760 to 19,454 and from 17,968 to 25,905. Additionally, the number of grinders and fractionation equipment represented in the BFL has increased. For many of these size-reduced and fractionated samples, moisture and particle characterization data have been collected and can be found in the BFL.

[7] Sluiter, J., Sluiter, A. (2011). Summative Mass Closure. Laboratory Analytical Procedure (LAP) Review and Integration. Technical Report NREL/TP-510-48087. https://www.nrel.gov/docs/gen/fy11/48087.pdf

[8] Wolfrum, E., Sluiter, A. (2009) Improved multivariate calibration models for corn stover feedstock and dilute-acid pretreated corn stover. Cellulose 16(5), 567–576.

[9] Hong, C.O., Owens, V.N., Bransby, D. et al. (2014) Switchgrass Response to Nitrogen Fertilizer Across Diverse Environments in the USA: a Regional Feedstock Partnership Report. Bioenerg. Res. 7, 777–788. https://doi.org/10.1007/s12155-014-9484-y

[10] Serapiglia, M.J., Cameron, K.D., Stipanovic, A.J. et al. (2009) Analysis of Biomass Composition Using High-Resolution Thermogravimetric Analysis and Percent Bark Content for the Selection of Shrub Willow Bioenergy Crop Varieties. Bioenerg. Res. 2, 1–9. https://doi.org/10.1007/s12155-008-9028-4

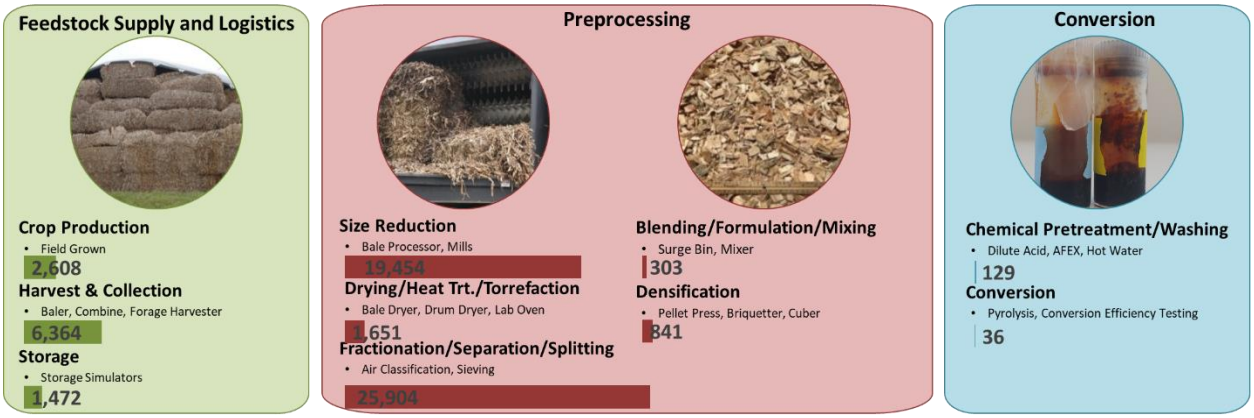


Figure 4. Equipment examples and number of samples for various unit operation categories represented in the BFL.

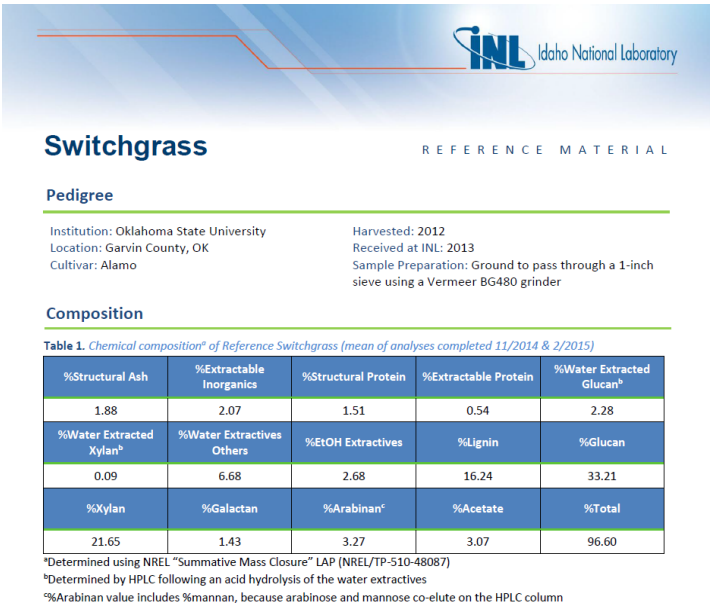
Researchers at INL's BFNUF address barriers facing the U.S. bioenergy industry (BFNUF). Specifically, the BFNUF is focused on these key areas that are critical to producing conversion-ready feedstocks from a variety of biomass and waste carbon sources: advanced feedstock supply logistics, post-harvest quality management, material handling, preprocessing, scale-up and advanced fractionation, and separation technologies. Beginning in 2020, the BFNUF initiated a three-year equipment upgrade to expand preprocessing capabilities in size reduction, fractionation, sorting, and conditioning. The equipment upgrade aims to advance this facility to allow researchers to address risks related to material flowability, source variability, equipment performance, and poorly defined feedstock specifications, which have caused production issues for bio-renewable fuels. The BFL, as a key component of the BFNUF, supports the incorporation of the new upgraded preprocessing equipment and unit operations.

5. Samples Available for Request

The BFL has physical biomass samples available for request. Researchers from government, academia, and industry organizations can contact the BFL Librarian or other BFL team members to inquire about sample availability (BFL Contacts). In addition, requests can be made for samples using the BFL sample request form page (Request Biomass). Samples are archived in the BFL from many BETO-funded projects and are provided based on availability. Three primary sets of biomass samples available publicly include biomass from INL's reference materials, samples generated from the Regional Feedstock Partnership (RFP) field trials, and samples generated from the Feedstock Conversion Interface Consortium (FCIC) project. Many other physical samples are available in the BFL by request from bioenergy researchers. Starting in FY 2024, the BFL will work to update the website to facilitate requests for a larger number of available physical samples in addition to the reference materials, RFP, and FCIC samples.

5.1. INL Reference Materials

INL's reference materials are industrially relevant, real-world biomass samples freely available in gram to kilogram quantities with associated characterization data sheets (Figure 5, Biomass Info). The reference materials were originally generated through a BETO-funded project with the intention of creating a sharable feedstock resource. Most of these samples were processed by INL in bulk, split, and characterized between 2015 and 2016; however, new reference material samples are added to either refresh feedstock types that are almost depleted or to add additional relevant feedstocks (e.g., MSW) as funding permits. The reference materials currently available include corn stover, switchgrass, miscanthus, sorghum, wheat straw, and sugarcane bagasse.



Idaho National Laboratory

Switchgrass REFERENCE MATERIAL

Pedigree

Institution: Oklahoma State University
Location: Garvin County, OK
Cultivar: Alamo

Harvested: 2012
Received at INL: 2013
Sample Preparation: Ground to pass through a 1-inch sieve using a Vermeer BG480 grinder

Composition

Table 1. *Chemical composition[a] of Reference Switchgrass (mean of analyses completed 11/2014 & 2/2015)*

%Structural Ash	%Extractable Inorganics	%Structural Protein	%Extractable Protein	%Water Extracted Glucan[b]
1.88	2.07	1.51	0.54	2.28
%Water Extracted Xylan[b]	**%Water Extractives Others**	**%EtOH Extractives**	**%Lignin**	**%Glucan**
0.09	6.68	2.68	16.24	33.21
%Xylan	**%Galactan**	**%Arabinan[c]**	**%Acetate**	**%Total**
21.65	1.43	3.27	3.07	96.60

[a]Determined using NREL "Summative Mass Closure" LAP (NREL/TP-510-48087)
[b]Determined by HPLC following an acid hydrolysis of the water extractives
[c]%Arabinan value includes %mannan, because arabinose and mannose co-elute on the HPLC column

Figure 5. Excerpt from switchgrass reference material data sheet.

Figure 6 provides details of the reference materials tracked and shared with researchers over the past decade through the BFL. The amounts shared from these materials have ranged from hundreds of grams to hundreds of kilograms. The number of requests from individual institutions ranges from 10 to 25 groups each year, with each group requesting one or more reference materials at a time. The BFL has also been collecting the resulting products, including publications and technical reports, that are associated with the reference materials. This information is being tracked in the BFL's citation feature, where references associated with individual samples can be viewed throughout the BFL database. Some of the new reference materials expected to be available in FY 2024 include MSW plastic and paper-rich streams, oilseed crop residues, and guayule.

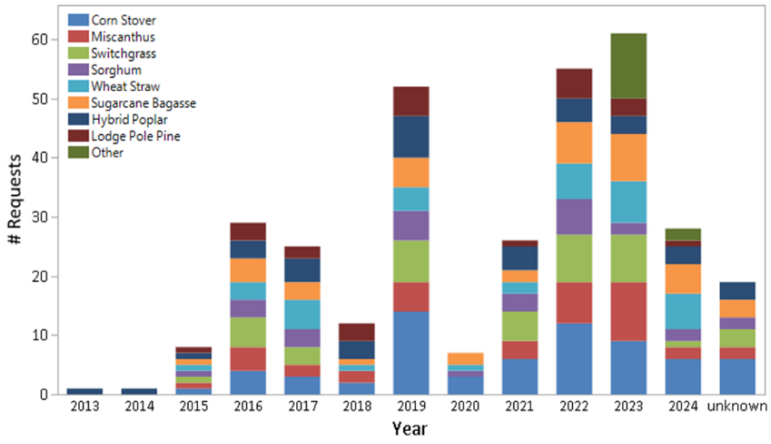


Figure 6. Requests for reference materials in the BFL from 2013 through 2024.

5.2. National Field Trial Samples

The Sun Grant RFP's large field trial-based project was developed to fill information gaps and validate biomass yield assumptions from the U.S. DOE Billion-Ton Study.[11,12] The series of field trials included nine bioenergy feedstocks grown in diverse environments across the United States for five to seven years. The field trials conducted by the RFP led to over 130 scientific publications and were critical in developing both the U.S. Billion-Ton Update report from 2011 and the 2016 Billion-Ton Report.[13,14] The BFL archived samples from these field trials, resulting in over 4,000 biomass samples that have been processed to an approximately 2 mm particle size and are available like the reference material in quantities up to one kilogram (Figure 7). Samples are from a variety of agricultural residues and energy crops, including corn stover, energycane, miscanthus, mixed perennial grasses, shrub willow, sorghum, and switchgrass. Data sets of biomass chemical quality are also available in the BFL for the RFP field trial samples. The links are provided in the Data Sets section of this report. Summaries of the chemical quality data were also published in the Regional Feedstock Partnership Biomass Quality Assessment Final Report.[15]

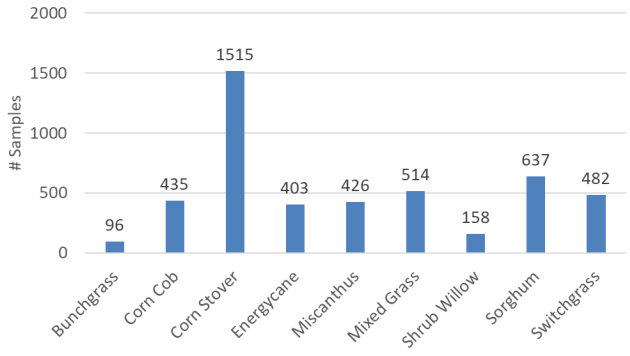


Figure 7. BFL archived energy crops and agricultural residues from the RFP field trials.

To further enable the use of purpose-grown energy crops, as were included in the RFP studies, a new DOE-funded initiative, the Regional Biomass Resource Hub Initiative (RBRH),[16] will continue to build on the research and success of the RFP by addressing research challenges associated with the mobilization of feedstocks. As with the RFP, the BFL will continue to function as an archival resource for samples generated as part of the RBRH.

[11] Owens, V. N. (2018). Sun Grant/DOE Regional Feedstock Partnership: Final Technical Report. DOE SDSU-85041, South Dakota State University, Brookings, SD, USA. Retrieved from: https://www.osti.gov/servlets/purl/1463330/.

[12] Owens, V. N., D. L. Karlen, and J. A. Lacey, et al. (2016). Regional Feedstock Partnership Report: Enabling the Billion-Ton Vision. INL/EXT-15-37477. U.S. Department of Energy and Idaho National Laboratory, Idaho Falls, ID, USA. Retrieved from: https://www.energy.gov/sites/prod/files/2016/07/f33/regional_feedstock_partnership_summary_report.pdf.

[13] U.S. Department of Energy. (2011). U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry. R. D. Perlack and B. J. Stokes (Leads), ORNL/TM-2011/224. Oak Ridge National Laboratory, Oak Ridge, TN, USA. Retrieved from: https://www.energy.gov/sites/default/files/2015/01/f19/billion_ton_update_0.pdf.

[14] U.S. Department of Energy. (2016). 2016 Billion-Ton Report: Advancing Domestic Resources for a Thriving Bioeconomy, Volume 1: Economic Availability of Feedstocks. M. H. Langholtz, B. J. Stokes, and L. M. Eaton (Leads), ORNL/TM-2016/160. Oak Ridge National Laboratory, Oak Ridge, TN, USA. Retrieved from: http://energy.gov/eere/bioenergy/2016-billion-ton-report.

[15] Emerson, R. M, et al. "Regional Feedstock Partnership Biomass Quality Assessment Final Report." United States. https://doi.org/10.2172/1862678.

[16] Regional Biomass Resource Hub Initiative. https://regionalbiomassresourcehub.inl.gov/

5.3. Feedstock Conversion Interface Consortium

The Feedstock Conversion Interface Consortium (FCIC) represents a collaborative network of nine U.S. DOE National Laboratories.[17] The FCIC research goals focus on identifying and addressing technical risks faced by integrated biorefineries. Through the FCIC research, large sample sets have been generated representing industrially relevant corn stover and loblolly pine feedstocks (Figure 8). The corn stover samples represent variability across four counties in Iowa for ash and harvest moisture levels. There are approximately 230 samples corn stover samples available from these locations in formats ranging from unprocessed bale core samples to materials milled to pass a 1-inch screen and 2-mm screen.

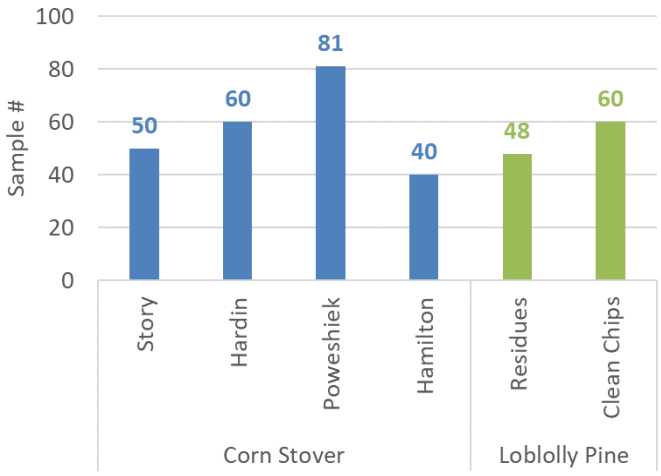


Figure 8. FCIC corn stover and loblolly pine samples available for sharing based on location (corn stover) and format representation (loblolly pine).

The available loblolly pine feedstocks harvested from two states in the Southeast represent "clean" wood samples generated from whole trees, which have their bark removed, and residues representing the tops of harvested trees, including bark, branches, and needles. The loblolly pine formats include samples that have been milled to pass 1/4-in., 3/4-in., and 2-mm screens. More information on the corn stover and loblolly pine samples can be found in FCIC-related publications.[18,19]

These sample sets have been archived in the BFL and are being made publicly available along with the analytical data and links to associated FCIC publications. As with the reference materials and RFP samples, corn stover and pine samples in amounts of up to one kilogram can be requested by contacting the BFL Librarian or other BFL team members (BFL Contacts) or by using the BFL sample request form page (Request Biomass).

6. Sample Archival

The BFL aims to make commercially relevant biomass and waste samples publicly available for research use. To support this objective and gain additional value from DOE BETO-funded bioenergy research, the BFL archives biomass and waste samples across multiple DOE BETO Renewable Carbon Resources program-funded competitive projects. These projects are required to send physical samples to the BFL along with relevant metadata and analytical data associated with the samples. Each project has its own partnership with the BFL, for which a Sample and Data Management Plan details how samples will be archived, analyzed, and shared; how long samples will be retained; how data will be managed and shared;

[17] Office of Energy Efficiency and Renewable Energy. n.d. "Feedstock-Conversion Interface Consortium." Bioenergy Technologies Office. Last modified 2023. https://www.energy.gov/eere/bioenergy/feedstock-conversion-interface-consortium. https://www.energy.gov/eere/bioenergy/feedstock-conversion-interface-consortium.

[18] A. E. Ray, et al. 2020. Multiscale Characterization of Lignocellulosic Biomass Variability and its Implications to Preprocessing and Conversion: A Case Study for Corn Stover. ACS Sustainable Chemistry & Engineering 8 (8): 3218–3230. https://pubs.acs.org/doi/full/10.1021/acssuschemeng.9b06763.

[19] J. L. Klinger, et al. 2020. Pilot Plant Reliability Metrics for Grinding and Fast Pyrolysis of Woody Residues. ACS Sustainable Chemistry & Engineering 8 (7): 2793–2805. https://pubs.acs.org/doi/full/10.1021/acssuschemeng.9b06718.

and necessary data set disclaimers and other pertinent details. Samples and data from these projects will be made publicly available according to each project's plan.

The BFL team has been working with projects funded by the BETO FY 2018 Affordable and Sustainable Energy Crops (ASEC) Funding Opportunity Announcement (FOA),[20] BETO FY 2020 Multi Topic Funding Opportunity FOA Topic Area 4,[21] the FY 2021 BETO Feedstocks FOA Topic Area 1,[22] the FY 2022 BETO Feedstocks FOA Topic Area 1,[23], and the Reducing Agricultural Carbon Intensity and Protecting Algal Crops (RACIPAC) FOA Topic Area 1.[24] To date, the BFL has archived over 2,300 samples across the 20 projects funded through these awards. Table 2 provides a high-level summary of the resources that have been archived as a result of these funding opportunities thus far. These samples and data will be made available according to their Sample and Data Management Plans.

Table 2. Summary of samples archived from BETO's recent funding opportunities.

Funding Opportunity	Research Focus[a]	Feedstock Types	Sample Count
FY 2018 Affordable and Sustainable Energy Crops	Early-stage research and development related to the production of affordable and sustainable purpose-grown energy crops to produce biofuels and coproducts.	Miscanthus, Switchgrass, Big Bluestem, other grassland species/varieties, Sorghum, Energycane	2100
BETO FY 2020 Multi Topic Funding Opportunity FOA Topic Area 4	Research focused on 1) targeting the appropriate places to produce or harvest biomass to deliver ecosystem services, 2) measuring, verifying, and valuing those ecosystem services in a scientifically rigorous manner, and 3) reducing uncertainty in modeled estimates of ecosystem services.	Hybrid Poplar, Eastern Cottonwood, Energycane	103
FY 2021 BETO Feedstocks FOA Topic Area 1	Increase understanding of the potential for municipal solid waste as bioenergy resource.	Variety of municipal solid waste fractions and resource representations	234
Funding Opportunity	Research Focus[a]	Feedstock Types	Sample Count
FY 2018 Affordable and Sustainable Energy Crops	Early-stage research and development related to the production of affordable and sustainable purpose-grown energy crops to produce biofuels and coproducts.	Miscanthus, Switchgrass, Big Bluestem, other grassland species/varieties, Sorghum, Energycane	2100

[a] Focus specific to the topic/sub-topic area of the funding opportunities related to the archived samples.

[20] Office of Energy Efficiency and Renewable Energy. 2018. "Affordable and Sustainable Energy Crops." Bioenergy Technologies Office. Last accessed October 20, 2023. https://www.energy.gov/eere/bioenergy/affordable-and-sustainable-energy-crops.

[21] Office of Energy Efficiency and Renewable Energy. 2020. "Bioenergy Technologies Office Fiscal Year 2020 Multi-Topic Funding Opportunity Announcement – Project Selections." Bioenergy Technologies Office. Last modified July 31, 2020. https://www.energy.gov/eere/bioenergy/articles/bioenergy-technologies-office-fiscal-year-2020-multi-topic-funding.

[22] Office of Energy Efficiency and Renewable Energy. 2021. "Department of Energy Announces Nearly $34 Million to Advance Waste and Algae Bioenergy Technology." Bioenergy Technologies Office. Last modified July 31, 2020. https://www.energy.gov/eere/bioenergy/articles/department-energy-announces-nearly-34-million-advance-waste-and-algae

[23] Office of Energy Efficiency and Renewable Energy. 2022. "Department of Energy Announces $29.5 Million for Improved Bioenergy Resource Recovery and Conversion Systems." Bioenergy Technologies Office. Last modified August 31, 2022. https://www.energy.gov/eere/bioenergy/articles/department-energy-announces-295-million-improved-bioenergy-resource.

[24] Office of Energy Efficiency and Renewable Energy. 2023. "U.S. Department of Energy Awards $23.6 Million to Support Production of Low-Carbon Biofuels and Bioproducts" Bioenergy Technologies Office. Last modified August 12, 2023. https://www.energy.gov/eere/bioenergy/articles/us-department-energy-awards-236-million-support-production-low-carbon

7. Data Sets

There are multiple ways to access sample information and data for the various bioenergy resources in the BFL. One mechanism the BFL uses to make data and sample information accessible is through data sets. A data set is a compilation of meaningful and curated data and sample information, for example, the samples and data associated with a peer-reviewed publication or industrially relevant data sets that have been requested by industry. There are currently 17 available BFL data sets that can be found on the BFL website (Data Sets). Data sets marked as public do not require a BFL login to access. RFP data, discussed in the Samples Available for Request section, including chemical quality data, have been made available as a data set for each feedstock type. This includes data sets for energycane (Data Set 1013), mixed perennial grasses (Data Set 1004), miscanthus (Data Set 1001), sorghum (Data Set 1003), switchgrass (Data Set 1002), and willow (Data Set 1005).

8. Summary

Biomass variability in the form of physical or chemical characteristics continues to be a primary challenge to integrated biorefineries achieving continuous operation and meeting yield requirements necessary for commercial-scale biofuels and chemicals. Challenges resulting from biomass variability range from microbial degradation in storage and plugged conversion processing equipment to potential health hazards and incomplete conversion. These challenges increase conversion costs for biofuel and bioenergy producers. There are multiple gaps in understanding biomass variability, including the diverse array of sources impacting the range of variability in biomass properties and how this variability impacts processing. The BFL seeks to address these gaps to decrease and provide as much information as possible to an emerging biorefining industry.

The BFL furthers understanding of biomass variability by providing a centralized, publicly available location that is readily and easily accessible and understandable to bioenergy researchers and industry stakeholders. The BFL is quickly becoming the most comprehensive, actively managed, living database of its kind, which is continuously updated with new samples and data. This database provides tools to store, record, track, retrieve, and analyze data to help researchers and industry overcome challenges posed by biomass variability. Together, BFL and BFNUF researchers provide industry with a resource to address challenges at the interface between feedstocks and conversion. The result is a better understanding of feedstock convertibility and processability.

Many of the BFL data resources can be accessed without requiring an account; however, to access all of the publicly available information the BFL has to provide, registration is required. Registration for the BFL is easy and free. To register for an account, visit the Registration page. For more information regarding the BFL, specific data availability, or other questions please visit our Contact Us page.