FEEDSTOCK SUPPLY AND LOGISTICS

TECHNOLOGY AREA

CONTENTS

INTRODUCTION

Six external experts from industry and academia reviewed 20 projects (18 presentations) during the Feedstock Supply and Logistics (FSL) portion of the 2017 Bioenergy Technologies Office (BETO or the Office) Project Peer Review. This review addressed a total U.S. Department of Energy (DOE) investment of approximately $99,822,002, or 14% of the BETO portfolio. During the Project Peer Review meeting, the principal investigator (PI) for each project was given 15–60 minutes to deliver a presentation and respond to questions from the Technology Area Review Panel. Allotted time was dependent on funding level and relative importance to achieving BETO goals.

The Review Panel evaluated and scored projects based on the outlined review criteria (approach, technical progress and accomplishments, relevance to BETO goals, and future plans). This section of the report contains the results of the project review, including full scoring information for each project, summary comments from each reviewer, and any public response provided by the PI. Overview information on FSL, full scoring results and analysis, the Review Panel's summary report, and BETO's programmatic response are also included in this section.

BETO designated Dr. Alison Goss Eng and Dr. Steven Thomas as the FSL Technology Area Review Leads. In this capacity, Dr. Goss Eng and Dr. Thomas were responsible for all aspects of review planning and implementation.

FSL OVERVIEW

As the raw material for biomass-to-biofuels, bioproducts, and biopower value chains, a sufficient and secure supply of affordable, high-quality feedstocks is critical to accomplishing Office goals and enabling a meaningful and sustainable biomass conversion industry. FSL research and development (R&D) relates directly to, and strongly influences, many, if not all, of the downstream elements of the Office's portfolio and its respective goals and objectives.

The scope of the FSL Program includes terrestrial, lignocellulosic feedstocks (i.e., agricultural res¬idues, forest resources, and dedicated energy crops), and select municipal solid waste (MSW) resources. Algae is only included as a blending agent (the Advanced Algal Systems Program was reviewed separately). The FSL Program encompasses sustainable feedstock production, resource assessment, and feedstock logistics operations up to the throat of the conversion reactor. These activities are directed at the following activities:

- Reducing the delivered cost of feedstock
- Improving and preserving the quality of harvested feedstock
- Improving environmental performance of feedstock production and logistics operations
- Expanding the volume of affordable, high-quality feedstock materials accessible to the developing bioenergy industry.

In addition, sustainable feedstock production R&D activities are focused on enabling the availability of abundant, affordable, high-quality biomass materials in the feedstock supply chain. There are three primary activities asso¬ciated with sustainable feedstock production:

- Conducting resource assessments
- Validating the yield potential and sustainability of a variety of potential feedstock crops
- Characterizing the physical and chemical properties of cellulosic feedstock materials.

Resource assessment involves estimating current and future domestic biomass resources by type and geographic distribution at different price points. It also includes understanding and helping to improve quality attributes (e.g., moisture, ash, and carbon content) associated with those resources as a function of geography and price and evaluating the environmental sustainability constraints associated with accessing those biomass resources over time.

Feedstock logistics refers to the supply chain operations that occur between feedstock production sites and the biomass conversion reactor inlet. Activities in this area are primarily focused on how to most efficiently, inexpensively, and sustainably harvest and deliver high-quality biomass from a variety of crops to biorefinery end users. These operations include feedstock harvest and collection, storage, handling, preprocessing, and transport to the biorefinery.

Biomass may be transported between field or forest and conversion facility by truck, train, or barge using existing transportation infrastructure. Optimization of container (or biomass package) volumes and dimensions designed for moving biomass feedstocks that simultaneously reach both weight and volume limits would increase efficiencies in the feedstock supply chain and therefore decrease delivered feedstock cost. Existing transportation infrastructure demonstrates these efficiencies for many commodity materials. Preprocessing raw biomass to feedstocks with infrastructure-compatible characteristics can leverage key components of the existing infrastructure.

FSL SUPPORT OF OFFICE STRATEGIC GOALS

FSL's strategic goal of is to develop technologies to enable a sustainable, secure, reliable, and affordable supply of acceptable-quality terrestrial feedstock for the U.S. bioenergy industry in partnership with the U.S. Department of Agriculture (USDA) and other key stakeholders. This goal supports the long-term goal (beyond 2040) to develop technologies and methods that could sustainably supply more than 1 billion dry tons of biomass per year.

The FSL Program directly addresses and supports resource assessment, sustainable crop production, biomass characterization, harvest, collection, storage, preprocessing, and delivery of feedstock for all potential biomass conversion pathways.

FSL SUPPORT OF OFFICE PERFORMANCE GOALS

The FSL Program is also taking the lead on five BETO success indicators/milestones, as published in BETO's *Strategic Plan for a Thriving and Sustainable Bioeconomy*[2] and BETO's 2016 *Multi-Year Program Plan* (MYPP)[3]:

- By 2018, establish nationwide sub-county-level environmental impact criteria and logistics strategies for all potential energy crops, including agricultural and forestry residues, annual and perennial herbaceous energy crops, and short-rotation woody energy crops
- By 2019, develop and provide a framework for multiple distributed processing scenarios for utilization of high-impact biomass feedstocks leading to commoditization, standardization, and risk mitigation
- By 2020, establish a vibrant and effective stakeholder engagement initiative coordinated within and between DOE, USDA, the U.S. Environmental Protection Agency, and other federal agencies to enable joint initiatives to advance and expand the U.S. bioeconomy

[1] U.S. Department of Energy, Bioenergy Technologies Office (BETO), *Strategic Plan for a Thriving and Sustainable Bioeconomy* (BETO, December 2016), https://www.energy.gov/sites/prod/files/2016/12/f34/beto_strategic_plan_december_2016_0.pdf.

[2] U.S. Department of Energy, Bioenergy Technologies Office (BETO), *Multi-Year Program Plan* (BETO, March 2016), https://www.energy.gov/sites/prod/files/2016/07/f33/mypp_march2016.pdf.

- By 2021, develop and verify cellulosic FSL systems that economically and sustainably supply 258 million dry tons per year (excluding biopower) at a delivered cost of $84/dry ton ($2014) to support a biorefining industry utilizing diverse biomass sources
- By 2022, verify at pilot or demonstration scale cellulosic FSL systems that can economically and sustainably supply 285 million dry tons per year (excluding biopower) at a mature modeled delivered cost of $84/dry ton ($2014) to support a biorefining industry utilizing diverse biomass resources.

In addition, the FSL Program contributes substantially to the success indicators and milestones listed in the Feedstock-Conversion Interface Consortium (FCIC) chapter of this report and also supports the following success indicators and milestones led by other BETO program areas:

- By 2017, verify at pilot scale at least one technology pathway for hydrocarbon biofuel production, demonstrating a mature modeled price of $3/gasoline gallon equivalent (gge) with a greenhouse gas (GHG) emission reduction of 50% or more
- By 2018, in collaboration with BETO's Strategic Communications team, sponsor stakeholder engagement activities that seek to identify and enable markets for producers and users of biomass
- By 2018, complete a robust market analysis that identifies specific future commodity fuel and bioproduct markets of interest and the markets that will support technology development and scaling in the near and medium terms
- By 2018, develop a set of market indicators to track progress of the growing domestic energy and bioproduct industrial sectors
- By 2019, publish a multi-dimensional analysis that identifies and quantifies specific economic, environmental, and social benefits of a transition to a robust bioeconomy
- By 2020, provide an analytical framework for bioproducts research by publishing market and life-cycle analyses, roadmaps, and/or reports
- By 2020, complete construction and initial operations for at least three pilot- and/or demonstration-scale integrated biorefineries to enable the subsequent development of pioneer commercial plants for advanced biofuels and bioproducts
- By 2022, verify at pilot or demonstration scale two additional pathways for hydrocarbon biofuel production at a mature modeled price of $3/gge with a GHG emissions reduction of 50% or more with the option of incorporating a bioproducts strategy
- By 2022, verify modeled techno-economic feasibility of nth-plant $3/gge from wet waste streams.

FSL APPROACH FOR OVERCOMING CHALLENGES

The milestones identified above need to be prioritized and addressed as funding permits in order to achieve the FSL's R&D goal to develop sustainable technologies that provide a secure, reliable, and affordable feedstock supply for the U.S. bioenergy industry. However, the following approaches are considered most critical and will be emphasized within the pro¬gram's efforts:

- Increase the volume of sustainable, acceptable qual¬ity, cost-effective feedstock available to biorefin¬eries by developing advanced feedstock supply systems and strategies
- Incorporate sustainability and feedstock supply risk into the resource assessments
- Work with the Conversion R&D Program to understand the range of acceptable physical and chemical in-feed specifications for the various conversion technology pathways under investigation
- Develop high-capacity, high-efficiency, low-cost, commercial-scale FSL systems that deliver stable, dense, flowable (in some cases), and consistent-quality infrastructure-compatible feedstock.

In the past, FSL Program research focused on modifying conventional terrestrial feedstock logistical systems that were designed and manufactured for traditional agricultural and forestry industries. Conventional systems are possibly suitable for high biomass-yielding regions but not for medium-to-low-yielding areas. Supplying feedstock to a growing bioenergy industry requires increasing the accessible volumes of lignocellulosic feedstock, while increasing the empha¬sis on quality, as well as reducing variability and risk throughout the value chain.

FSL REVIEW PANEL

Name	Affiliation
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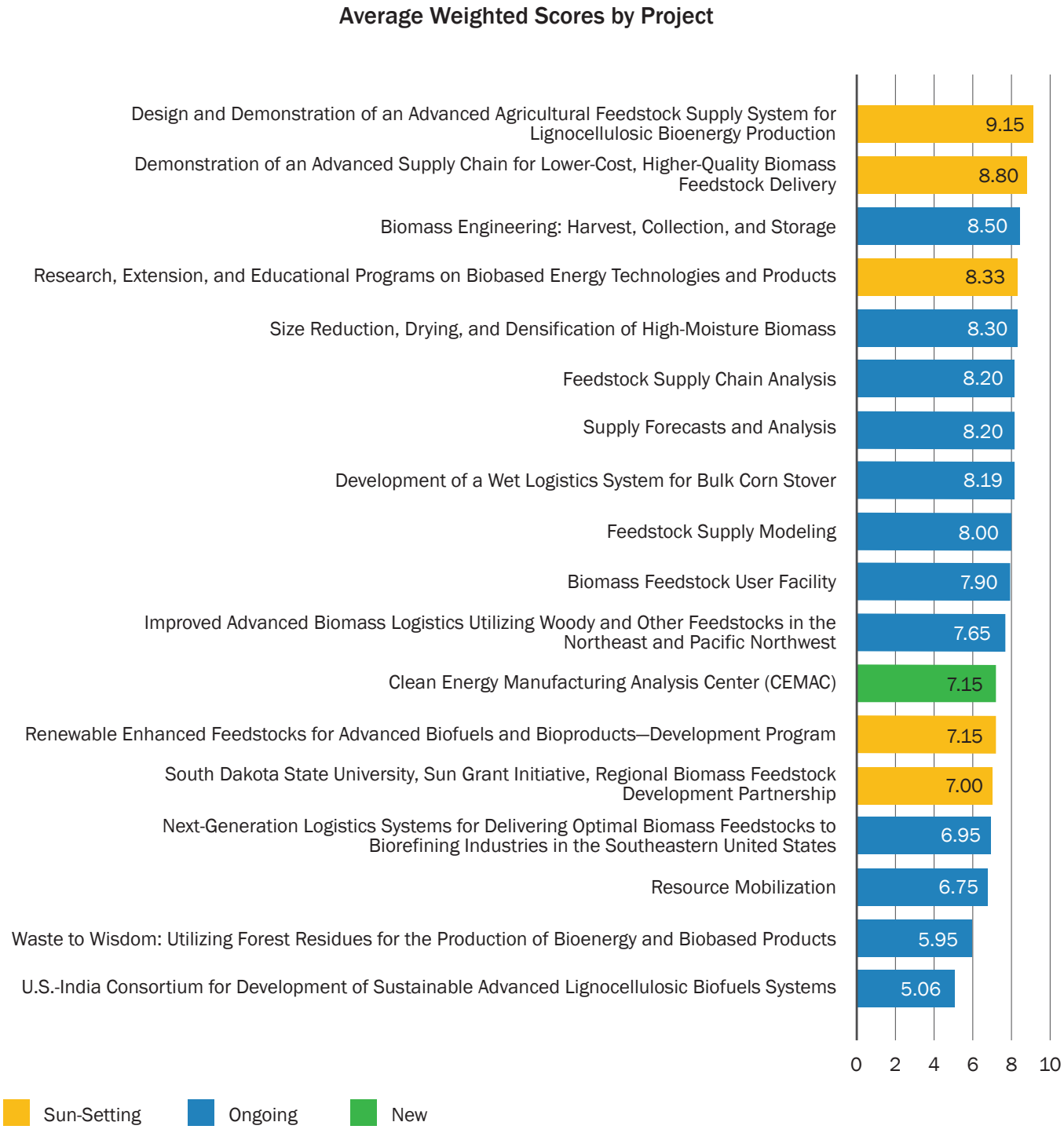
TECHNOLOGY AREA SCORE RESULTS



FSL REVIEW PANEL SUMMARY REPORT

Prepared by the FSL Review Panel

The suite of projects reviewed represented a full range of FSL topics, ranging from genetic manipulation of energy crops to national level analysis of feedstock supplies. As a group, they are intended to address the availability of biomass in sufficient quantity, quality, and cost to support the developing bioenergy industries. Review and analysis of the individual projects and the entire FSL Program was conducted in light of the observations and recommendations made in the fiscal year (FY) 2015 Peer Review.

Impact

BETO projects have a positive effect on the confidence in predicted feedstock availability and delivered cost estimates. Advancements in scientific understanding of regional energy crop/residue yields and the development of improved technologies for biomass collection, storage, and preprocessing have enhanced the development of business models necessary for commercial adoption. The diversity of funded projects has addressed most aspects of the systems needed to supply biorefineries. However, the portfolio includes some activities for which the Review Team had differing opinions regarding the value provided.

Projects viewed as having significant positive impact include the following:

- The Regional Feedstock Partnership coordinated by North Central Sun Grant Center has generated knowledge on biomass production of multiple crops across years and locations and provided the scientific underpinning for the *2016 Billion-Ton Report: Advancing Domestic Resources for a Thriving Bioeconomy (BT16)*.
- Supply forecasts and analysis for *BT16* built on the operational and economic data gathered on yields and logistics systems to provide an increased level of sophistication in the prediction of the scope of a potential biofuels industry. The addition of sustainability estimates for biomass production systems addresses concerns by some industry critics and directly addresses recommendations of the 2015 Peer Review.
- Advanced logistics systems for crop residues, as well as herbaceous and woody crops, provide improved collection and delivery systems that support the nascent biofuels industry and create new machines and processes.
- Idaho National Laboratory's (INL's) projects to handle and store higher moisture biomass while maintaining quality and quantity have the potential for high impact. Solutions are critically needed to expand the biofuels industry into more humid regions or situations where the biomass collection period is limited.

Projects judged to have lower impact attempted to predict future resource allocations or assess future equipment manufacturing needs. Markets will drive the utilization of biomass resources and the ramping up of equipment manufacturing, and BETO efforts could be better focused on short- to medium-term projects that address industry viability. Establishment of demonstration projects such as the North Central Sun Grant Eco-Farm that are unable to sustain long-term operation may increase knowledge and experience, but have limited impact toward the BETO goal. BETO-funded projects focused on genetic improvement of energy crops generally received more divergent scoring from the review team and the long-term impact of those projects is questionable.

Innovation

The bulk of BETO's portfolio projects are based on the application or refinement of known technologies with biomass residues and crops; a strategy appropriate for a program whose intent is to maximize biomass supply at reasonable cost. The majority of the portfolio should

be lower risk/higher probability of success projects. This strategy is working in most cases. However, in instances where the challenges are particularly intransigent, a limited number of higher risk projects should be considered.

Significant innovation has been demonstrated in multiple projects. Of particular note are the following:

- Near-infrared (NIR) sensing techniques for assessing the quality of biomass in bale form
- High tonnage logistics projects awarded from FY 2009 and FY 2013 advanced logistics funding opportunities
- New vehicle design for whole tree transport to facilitate an integrated log merchandising operation.

Topics requiring greater innovation include treatments that could reduce fire potential in stored biomass without affecting the conversion efficiency, non-contact mapping of moisture content variability within bales, and bulk handling and storage of high moisture biomass at or below BETO target costs.

Synergies

Significant levels of synergy within the BETO portfolio were described during the review. Examples include the following:

- The Sun Grant Feedstocks Partnership providing crop yield potentials that were modeled in the PRISM-ELM software and used to conduct *BT16*
- Logistics equipment and systems developed with BETO funding that are facilitating the operations of the Poet and DuPont biorefineries in Iowa
- Interaction between projects at the various DOE national laboratories
- The Biomass Feedstock National User Facility (BFNUF) and the establishment of the FCIC.

Interactions described between the PIs of various projects give additional confidence that synergies are real and effective.

Opportunities remain for increasing synergies within the FSL portfolio and across other BETO program/technical areas, particularly the Conversion R&D Program. Several projects were already part of the FCIC grouping, but specific individual projects were recommended for inclusion in FCIC. Greater synergy could be gained across multiple projects by incorporating the developing biomass quality sensing techniques and providing the capability of utilizing those quality measures in the optimization of the biorefinery or storage strategies.

Focus

The BETO FSL Program has successfully projected future availability of biomass as well as equipment and labor needs to support a biofuels industry of a size to meet the Renewable Fuel Standard (RFS) targets. The challenge facing BETO now is getting a viable industry started and demonstrating the profitability of biofuels sufficiently to attract investment capital. Going forward, the focus of the FSL program should be on solving the short- to medium-term challenges of supplying biomass at sufficient quantity, quality, and delivered cost, and less on projecting longer-term performance. The current portfolio does include projects that address the nearer-term challenges and funding should be reduced for analysis projects (e.g., supply forecasts and analysis; resource mobilization; the Clean Energy Manufacturing Analysis Center [CEMAC], etc.) and enhanced in those projects that directly address issues the industry is facing today (e.g., quality assessment, handling, storing and processing wet biomass, adaptive control systems to enhance capacity of unit operations such as grinding, drying and densification, and systems analysis for the entire stream of unit operations, etc.). Increased attention to the interactions between feedstock logistics and conversion should also be an area of focus. For example, some FSL projects address blending of biomass sources, but it is not clear that conversion processes are optimized with blended feedstock.

The FY 2015 Peer Review cautioned against mission creep, and evidence of that issue was present in some projects. An example is the addition of sugarcane aphid resistance of sorghum to the future work of the US-India Consortium project. A robust review of project activities by BETO staff is needed to detect and respond to such creep.

Commercialization

Relatively few outputs of BETO FSL projects have been commercialized. This is in large part because the cellulosic biofuels industry, and thus the demand for equipment by that industry, has not developed at the rate anticipated by the federal RFS. A number of the projects have produced products with potential for commercialization, and are waiting for a market demand. This is particularly true for the competitively awarded high tonnage logistics projects, which resulted from the FY 2009 and FY 2013 advanced logistics funding opportunities. Projects such as high moisture pelleting and adaptive control of grinding have significant potential for commercialization. However, rapid movement of technical advances into commercial production will need to be based upon auxiliary uses of the technology. Identifying potential uses of BETO developed technology in mature industries can be an effective strategy for ensuring the technology will be available for biofuel industry adoption when that industry does ramp up in size.

During review presentations about the Process Demonstration Unit (PDU) at INL, the Review Team was informed that the PDU is expected to be available to commercial firms for proprietary research on a fee basis, and to conduct BETO-sponsored research. In addition, INL management expressed that BETO wishes the PDU to be more self-supporting. The Review Team recognized a potential conflict between the roles of conducting BETO-directed research and generating income from commercial firms. This dual use of the facility also presents challenges in managing intellectual property (IP) when public and private entities collaborate in a facility. Appropriate strategies for IP management must be in place to support the commercialization of BETO technology.

Recommendations

BETO investments in projects to assess the potential for supplying a biofuels industry and developing the technologies needed to do so have been largely successful. Many lessons have been learned and processes or machines developed. However, much remains to be done if a biofuels industry is to become economically viable. Recommendations for individual projects are made in the summary comments for each, but the following are overall reviewer recommendations for BETO as it sets future objectives.

- Closer and more effective collaboration with USDA in setting priorities for research on biomass crops is needed. The Review Panel is aware that USDA has responsibility for the plant improvement aspects of feedstock development. Significant improvements in biomass crop characteristics are needed beyond yield gains, and BETO must collaborate with USDA—through the National Institute of Food and Agriculture (NIFA) and Agricultural Research Service—by providing desired phenological or chemical characteristics that plant breeders and agronomists should target in their research. The cooperation of USDA to include such needs in funding opportunities and project plans is needed. For example, reduction in lodging of high-yielding energy crops would improve harvest efficiencies and reduce ash content due to soil contamination. The Panel recognizes that cooperation with USDA has been underway for some time, so our recommendation is to continue to place an emphasis on communicating specific research needs that are recognized as enhancing BETO's goals.
- Increase emphasis on addressing the short- to medium-term feedstock and logistics issues that are a drag on biofuel industry efficiency and profitability. The Billion-Ton report series (including *BT16*, the *2011 U.S. Billion-Ton Update, and the Billion-Ton Study* published in 2005) have been quite successful in demonstrating the potential size of the bioecon-

omy, and now addressing the sustainability of that industry. Relatively modest value will be gained by continued refinement of that effort. Reallocation of funding from analytical projects to those more likely to stimulate the growth of the industry is needed. A billion-ton biofuels industry will be made up of 1,000 biorefineries processing 1 million tons each. It is more critical to focus on activities that will make those initial biorefineries successful. The industry will never reach a billion-ton demand unless several successful million-ton biorefineries first exist.

- The recommendation for a depot-level demonstration project was made in the FY 2015 Peer Review. Such a depot demonstration has not been initiated, so the team reiterates the importance of such a demonstration. While the operations of the PDU at INL perform some of the aspects that a depot demonstration would, the experience of operating such a depot for an extended length of time is one of those medium-term issues mentioned in the second recommendation. If BETO feels that it does not have the knowledge and systems in place to conduct such a demonstration, it should clearly identify the aspects that are lacking and identify those projects that are intended to provide the knowledge or systems as addressing the intent for a depot demonstration.

FSL PROGRAMMATIC RESPONSE

Introduction/Overview

The FSL Program would like to thank the 2017 FSL Peer Review Panel members for their service on the Review Panel and for their thorough analyses of the FSL portfolio of projects. We are indebted to the reviewers for their hard work and their objective and knowledgeable comments on the diverse projects that were reviewed.

The Review Panel recognizes the FSL Program's efforts and investments to increase confidence in estimating feedstock availability, energy crop yield, and logistical costs. Since these are important focus areas for the program, we thank the Panel members for recognizing and highlighting the successes of these core efforts, especially BT16, the Regional Feedstock Partnership, and innovation in feedstock technology development, application, and use. Members of the Panel are also complimentary on the synergy among these projects which has been an important goal for the program.

BETO's FSL Program has worked hard, through implementation of active project management principles, to coordinate and facilitate data production, and to ensure that the data are made available to maximize their usefulness. This includes data integration within the supply and logistics components as well as along the entire supply chain. Examples include the Bioenergy Feedstock Library[4] and the Bioenergy Knowledge Discovery Framework[5] (KDF). Reviewers also recognize the important role of the FSL Program working with industry. As examples, the reviewers mention the success of an industry equipment development project, FDC Enterprises Inc., in harvest, collection, and transport of biomass bales using an integrated approach. Also highlighted is the success of INL's biomass engineering project—a collaboration with industry partners to reduce moisture and soil contamination in corn stover bales. There are also very favorable comments on the cooperation with various universities across the country to quantify energy crop yields as a function of genetics, geography, and environment (especially soil and weather conditions).

[4] Visit the Bioenergy Feedstock Library at http://bioenergylibrarly.inl.gov.

[5] Visit the Bioenergy KDF at http://www.bioenergykdf.net.

The FSL Program welcomes the assessment of the positive impacts in scientific advancements and support of industry development for several projects. We also appreciate the Review Panel's input that some of the projects were much less impactful. Such projects are those that had a focus on future predictions of biomass allocations and equipment needs, or long-term field studies. The Panel suggests that the FSL Program would be better served with short- to medium-term projects that address industry viability. The FSL Program agrees that the focus should be on solving the short- to medium-term challenges of supplying biomass at sufficient quantity, quality, and competitive delivered costs. We also agree to the suggestion to reduce analysis projects, with the exception of such cases where analyses are needed to solve industrial viability challenges and issues.

The FSL Program appreciates the recognition of innovation in the portfolio while relying on known technology much of the time. We agree that there needs to be a mix of low- and high-risk research to achieve truly innovative technology. The effort placed on developing synergy among the projects and with other program areas is also recognized. We appreciate the positive comments as this has been a focus area for the FSL Program. The Panel's suggestions for improving synergy are welcomed.

Commercialization is still an ongoing issue for the FSL Program because of the lack of dynamic market conditions and the inherently slow implementation of new technology. FSL will look at the opportunities for application of such technology in ancillary uses as a way to ensure that the technology will be scaled up for use in the bioeconomy.

Recommendation 1: Increase Collaboration with USDA

Going forward, the FSL Program will work even more to improve communication of research priorities with USDA. We will also look to increase effectiveness of the following ongoing USDA collaborations, specifically as they relate to crop improvement, production, and management:

- USDA/DOE Biomass Feedstock Coordination Group quarterly meetings
- USDA/DOE national laboratory, research center, and station bioeconomy research collaboration meetings
- Five relevant interagency working groups, with coordination and exchange between two agencies (Feedstock Production and Management, Feedstock Production and Genetic Improvement, Feedstock Logistics, Sustainable Bioeconomy, and Analysis)
- Information exchanges on plant (crop) improvement and yield studies (Regional Feedstock Partnership, feedstock network, and field trials)
- USDA Peer Reviewers on most FSL projects
- Development and execution of the joint USDA-DOE Biomass R&D Initiative solicitation.

DOE and USDA will continue detail opportunities within each other's agencies, and will continue to take full advantage of the recently established Memorandum of Understanding to foster collaboration between the DOE national laboratories and USDA Agricultural Research Service, which resulted from a DOE employee going on assignment to USDA for 18 months. In addition, the FSL Program will include DOE Office of Science and Advanced Research Projects Agency-Energy in efforts to coordinate with USDA.

Recommendation 2: Emphasize Near-Term Goals

The FSL Program agrees that the primary focus of the program should be developing technologies to make biorefineries successful. With the potential of the bioeconomy well-established and quantified, moving forward, the emphasis will shift from asking "how much biomass is potentially available?" to "how can we mobilize potentially available biomass?"

Future work will now focus on (1) solving the near-term feedstock logistics issues by including and improving productivity, environmental effects, and feedstock quality parameters, and (2) developing preprocessing strategies to address feed handling problems faced by biorefineries in collaboration with the FCIC, with the goal of achieving greater operational reliability and cost targets.

Recommendation 3: Create Depot-Level Demonstration Project

BETO acknowledges and agrees with the need for a depot demonstration. Moving forward, BETO will continue to assess whether depot demonstration projects align with Administration priorities and are feasible within BETO's appropriations. Currently, demonstration projects do not align with the Administration's near-term priorities for BETO. BETO will conduct early stage R&D toward quality specifications and understanding fundamentals of feedstock preprocessing and handling. This will support industry in building on the knowledge for demonstration and scale-up activities.

In addition, INL's PDU capabilities will be leveraged to address feedstock handling and feeding problems, and the obtained unit operations specifications will continue to provide valuable information to integrate into FCIC and depot demonstration.

SUPPLY FORECASTS AND ANALYSIS

(WBS #: 1.1.1.1)

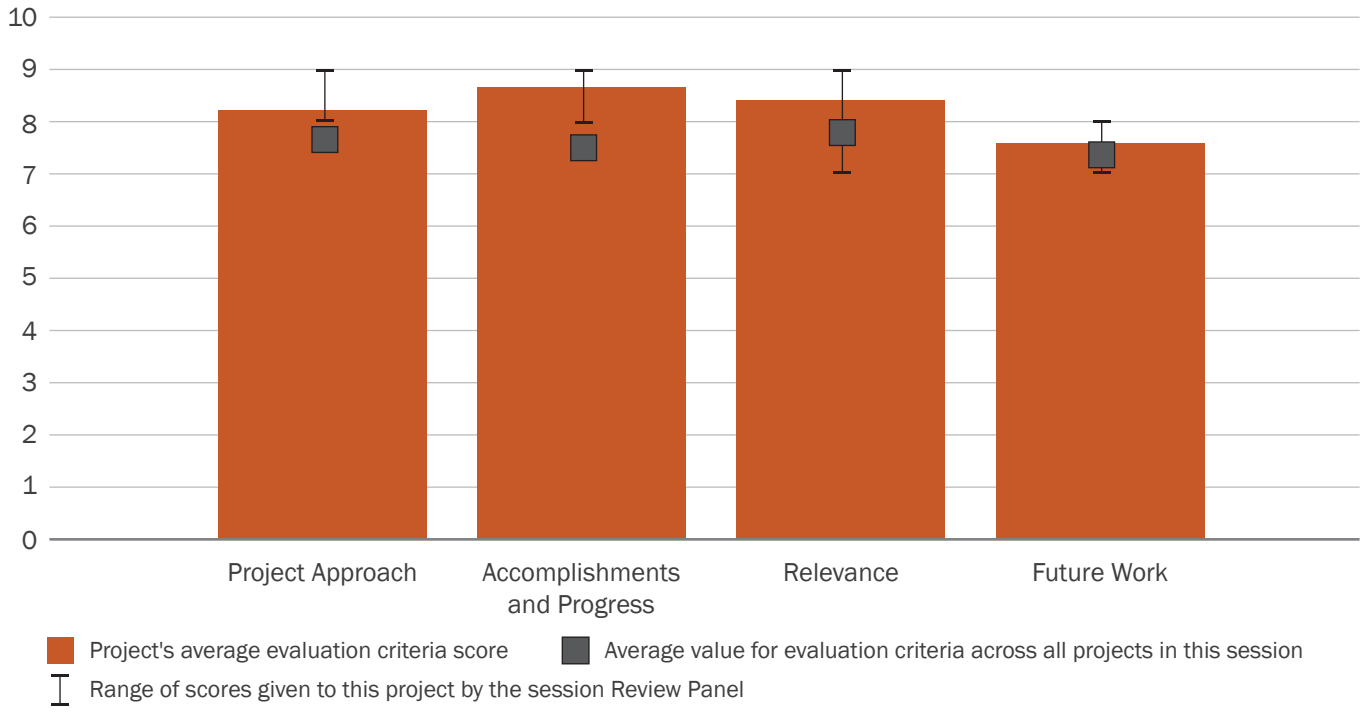
Project Description

Recipient:	Oak Ridge National Laboratory
Principal Investigator:	Matt Langholtz
Project Dates:	10/1/2006–9/30/2017
Project Category:	Ongoing
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$950,000
DOE Funding FY 2015:	$1,750,000
DOE Funding FY 2016:	$2,200,000
DOE Funding FY 2017:	$1,900,000

Realization of a bioeconomy vision is dependent upon biomass feedstock supplies. The economic viability of a biomass-based industry depends on feedstock quantity, quality, cost, and spatial and temporal distribution, as well as variability in these characteristics. This project provides data on the potential economic availability of biomass feedstocks. These data are critical to other R&D efforts in BETO and are used by other agencies and stakeholder groups. This effort employs an economic modeling framework (e.g., POLYSYS) to project county-level estimates of potential biomass supplies (e.g., agricultural residues, dedicated biomass feedstocks, and forest resources) as a function of price, scenario, and year. Ongoing modeling efforts include maintenance of current underlying data, incorporating up-to-date biomass crop yield and budget assumptions, adding additional feedstock types such as algae and MSW, evaluating reactor-throat-delivered estimates, and quantifying environmental sustainability impacts. Detailed results are disseminated through the KDF. This project produced BT16, including *Volume 1: Economic Availability of Feedstocks and Volume 2: Environmental Sustainability Effects of Select Scenarios from Volume 1*, along with online companion material on the Bioenergy KDF (bioenergykdf.net).

Weighted Project Score: 8.2

Weighting: For ongoing projects, there is equal weighting across all four evaluation criteria: Approach, Relevance, Accomplishments and Progress, and Future Work.



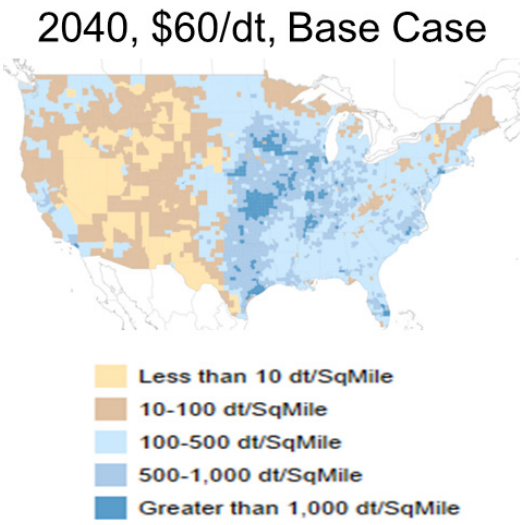


Photo Courtesy of Oak Ridge National Laboratory

Overall Impressions

- My overall impression is that this project continues to make amazing strides and advance the state of the art. It is truly impressive and valuable, and guides academic work priorities. In the future, this project needs to
  - Incorporate more nuanced and validated crop productivity and environmental impact data
  - Express results as a function of the status quo for fossil and commodity crops so the public and decision makers can realistically compare systems performance.
- This is a very significant and comprehensive approach to estimate and establish the availability of the biomass resources for the biorefinery industry. The sustainability component is an interesting development, but it needs very clear objectives to ensure this component adds value to the program.
- This project needs to include social aspects/social indicators on modeling.
- This is a well-done project has been a major contributor to *BT16* volumes 1 and 2 by identifying the supply and economic availability to the reactor throat at a county level and addressing the sustainability criteria of many feedstocks.

  These biomass assessments are critical to BETO's mission. Each of the three reports in the Billion-Ton study series (*BT16*, as well as the 2005 *Billion-Ton Study* and the 2011 *U.S. Billion-Ton Update*) has become increasingly more sophisticated in analysis. *BT16* has successfully documented the potential size of the bioeconomy, if the advances in feedstocks, logistics, and conversion ultimately make biofuels and co-products economically viable. Continued refinement of the biomass availability estimates will be of less importance than technical advancements that support industry growth.
- The sustainability assessment is the first step in identifying and understanding its benefits. The sustainability assessment is mainly focused on the environmental indicators. Social indicators need to be developed and vetted for its applicability to various biomass crops. Despite criticisms on the accuracy and the credibility of sustainability indicators, they could serve as a decision support tool to develop mitigation strategies and long-term environmental issues/benefits of locally grown biomass crops. BETO needs to determine how best to use the sustainability assessments in its role as an advocate for the biofuel industry.
- Overall, the project has accomplished key milestones related to the national biomass supply analysis study to demonstrate the wealth of biomass availability in the nation to build a strong and emerging bioindustry in the United States. The vast availability of low-cost feedstock has demonstrated the strength of our bioeconomy, while addressing key feedstock quality and cost risks. The project has a potential to address key biomass quality parameters within the assessment as required by the biorefinery.

PI Response to Reviewer Comments

- We agree that the crop productivity and environmental effects data can and should be improved. We agree that a "compared to what" analysis would elucidate comparative advantages of system performance, and will do so as programmatic goals allow.

We agree that social indicators can and should be added, and that results can and should be used in decision support tools to develop mitigation (or benefit maximization) strategies. To provide more benefit to end users, we agree that more feedstock quality parameters should be added to the analysis.

FEEDSTOCK SUPPLY CHAIN ANALYSIS

(WBS#: 1.1.1.2)

Project Description

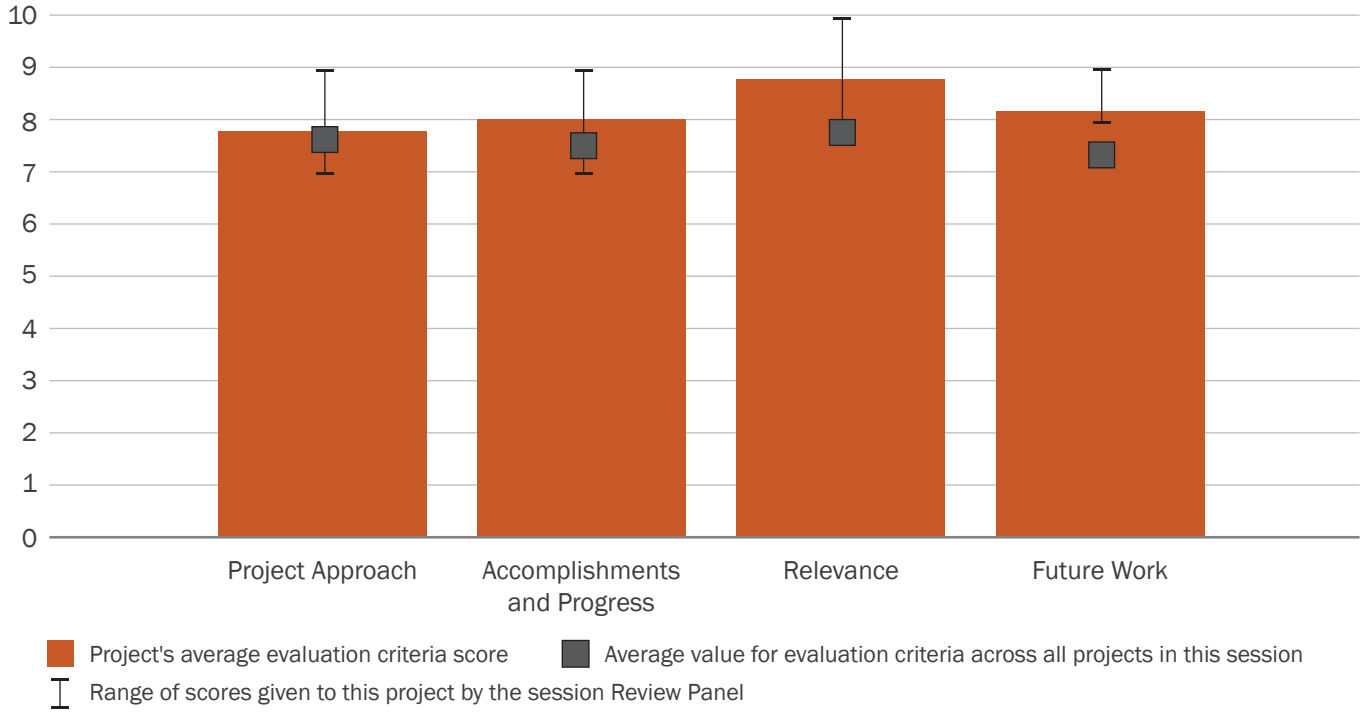
Today's infant biorefinery industry lacks a consistent and reliable biomass supply, and thus relies on vertical integration of its feedstock supply to minimize supply risk. However, the existing biomass supply is collected and supplied using conventional feedstock supply systems developed for industries that are less sensitive to feedstock quality and can thus utilize lower cost passive quality management. The overarching goal of this project is to provide BETO with credible, objective analyses of feedstock supply systems and strategies to support their investment in a sustainable, economically viable national scale bioenergy industry. This project directly informs BETO through barrier "Ft-M: Overall Integration and Scale-Up" in the MYPP.[6]

Recipient:	Idaho National Laboratory
Principal Investigator:	David Thompson
Project Dates:	10/1/2006–9/30/2017
Project Category:	Ongoing
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$450,000
DOE Funding FY 2015:	$585,000
DOE Funding FY 2016:	$765,000
DOE Funding FY 2017:	$900,000

This project develops and vets innovative strategies that meet cost, quantity, and quality specifications while minimizing environmental impacts, and delivers robust datasets and flexible analysis tools to enable industry to implement a successful biofuel supply system. This project also tracks progress toward the $84/ton modeled feedstock cost target, based on technology improve-

Weighted Project Score: 8.2

Weighting: For ongoing projects, there is equal weighting across all four evaluation criteria: Approach, Relevance, Accomplishments and Progress, and Future Work.



[6] U.S. Department of Energy, Bioenergy Technologies Office (BETO), *Multi-Year Program Plan* (BETO, March 2016), https://www.energy.gov/sites/prod/files/2016/07/f33/mypp_march2016.pdf.

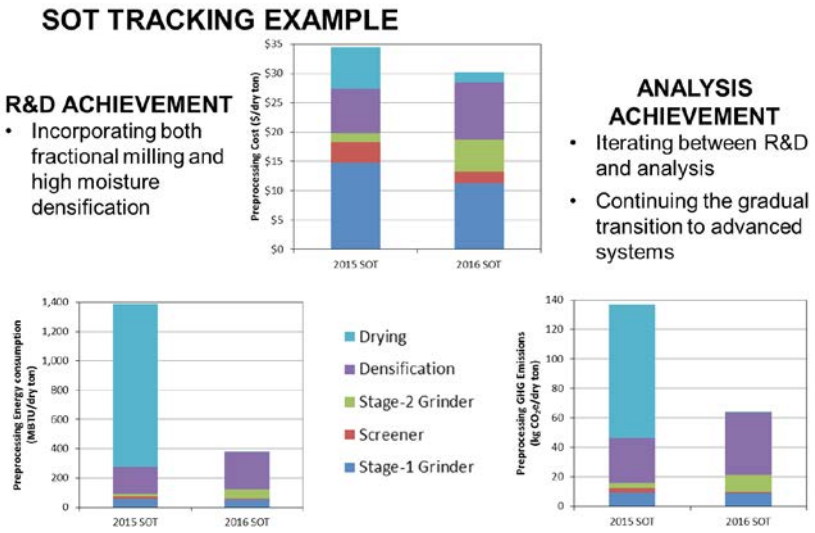


Photo Courtesy of Oak Ridge National Laboratory

ments identified annually in R&D activities. Historically, we have investigated conventional feedstock supply systems and several advanced (active quality management) feedstock supply system strategies including blending and commoditization of biomass to meet modeled cost, quantity, and quality specifications required to meet long-term U.S. biofuels production goals.

Overall Impressions

- This is a foundational project that evaluates effectiveness of BETO projects toward meeting BETO goals.
- Good model to measure and validate the progress of the program activities and to help in the decision-making process. As result of the analysis, there are a significant number of assumptions in the analysis and the tool that could benefit from a risk component to help define the uncertainty of the results.
- Provides guidance to BETO R&D. Confidence in selecting/evaluating new technologies is crucial.
- This is a good line of research that provides verification to track BETO's goals and guide R&D.
- This project provides fundamental analysis for BETO management that allows assessment of progress on the larger goals of the program. As such, this is a critical function that must be maintained within the program. That being said, the results presented can be criticized on several points. The analyses seem to indicate that BETO is being successful in meeting cost targets for delivered biomass, but the industry reality is that such targets are not being met. This leaves several questions, including the following: Are the modeled assumptions being too optimistic? The data presented gave only single value estimates at each point in time. What about including variance on the state-of-technology (SOT) estimates? Adding uncertainty to each of the number used in the analysis will certainly complicate the analysis, but would provide a better understanding of the real confidence in the estimates.
- Overall, the project has demonstrated that advanced supply logistics system could reduce the feedstock delivered cost to a target level, without compromising the quality of biomass. The future research will be carried forward in the right direction to improve feedstock quality reliability and reduce risks.

PI Response to Reviewer Comments

- In line with the conversion techno-economic analyses (TEAs), our design cases and SOTs present nth-plant scenarios that assume that all of the operational issues have been overcome, rather than the first-plant scenarios experienced by the pioneer

biorefineries. Beginning with our March 31, 2017 Go/No-Go Decision Point, in which we look at the impacts of reduced operational reliability due to feedstock properties, we have initiated this type of analyses. This analysis has allowed us to target fines generation and moisture content as the feedstock properties having the most impact on achievable throughput; while this is not the only issue experienced by the pioneer biorefineries, it is a significant one and we are working toward a solution.

Regarding uncertainty, this is a good comment, and we began integrating uncertainty analyses around assumptions in FY 2017. Unfortunately, while possible in the Biomass Logistics Model, Monte Carlo analyses are unwieldy and difficult to complete. To alleviate this limitation, we built Aspen Plus modules for the preprocessing operations during the first 4.5 months of FY 2017 (using the same experimentally-derived relationships among energy consumption, moisture content, etc. measured in the INL PDU) to allow the Monte Carlo analyses to be done more easily.

RENEWABLE ENHANCED FEEDSTOCKS FOR ADVANCED BIOFUELS AND BIOPRODUCTS (REFABB)

(WBS#: 1.1.2.2)

Recipient:	Yield10 Bioscience
Principal Investigator:	Oliver Peoples
Project Dates:	9/1/2011–2/28/2016
Project Category:	Sun-setting
Project Type:	FY 2010—BRDI: DE-FOA-0000341
Total DOE Funding:	$6,000,001

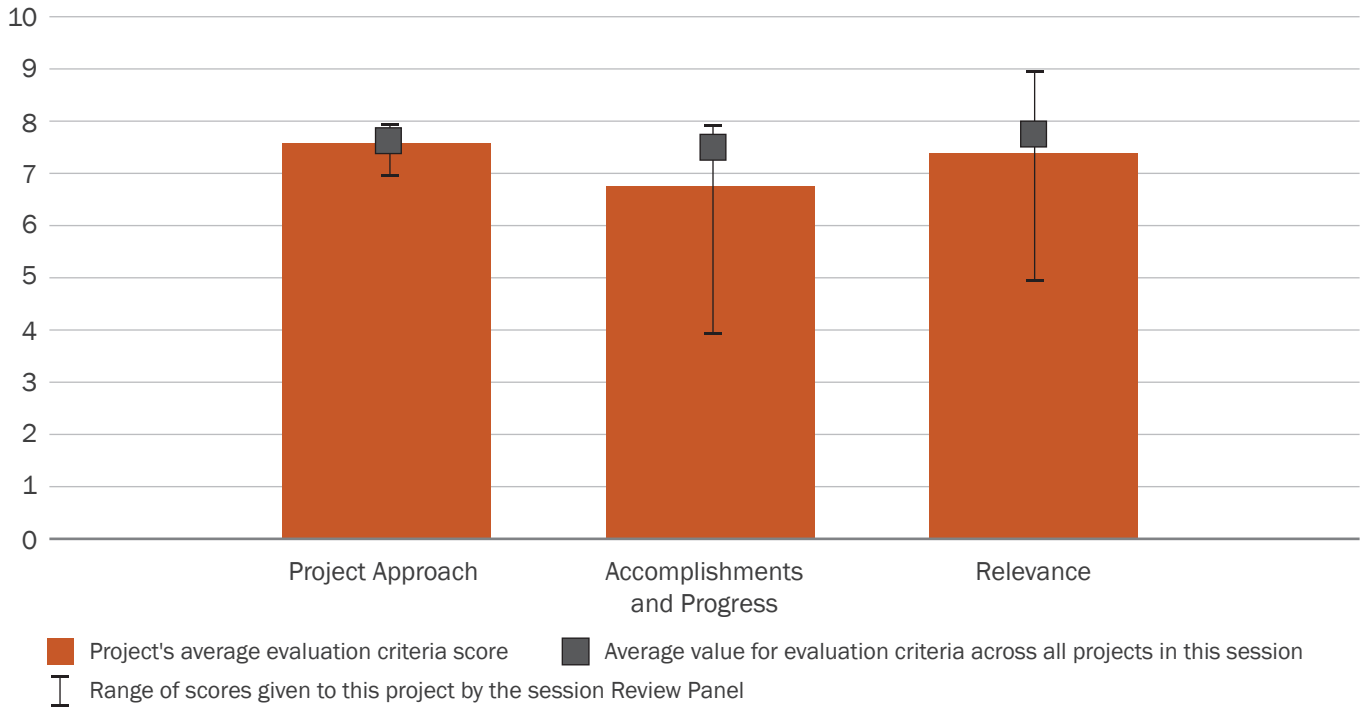
Project Description

Production of polyhdyroxybutyrate (PHB) in switchgrass enables small-scale thermolysis facilities to produce crotonic acid and densified biomass. Densified biomass can be transported to large-scale biofuel facilities or used directly as fuel. Crotonic Acid can be converted to butanol. The project addresses three key technology barriers, feedstock supply, feedstock logistics and cost-effective biomass conversion. This project adds to our understanding of the potential of developing a value-added biomass feedstock crop for bioproducts and biofuels.

Challenges in demonstrating conversion of PHB in biomass to crotonic acid at over 90% yield illustrates the limitations of trying to adopt existing equipment to a task for which it proved unsuitable, resulting in the project not being able to demonstrate a scalable economic process. Solving this will take further R&D work. Novel genetic engineering technologies were developed and PHB levels in switchgrass were increased up to 10%. Scalable conversion of crotonic acid to butanol was demonstrated and a lifecycle analysis completed. Genes for increasing photosynthesis were patented and are now being developed to enhance food crop production by Yield10 Bioscience.

Weighted Project Score: 7.2

Weighting: Approach–25%; Relevance–25%; Accomplishments and Progress–50%.



Overall Impressions

- This project is very ambitious and high risk. Major progress was made, but ultimately this project demonstrated the extreme challenges associated with switchgrass molecular breeding and coupled feedstock/processing improvement. Techniques used here are too time and resource intensive to test all the interactive components of the system needed to make progress. Exemplary project to illustrate limitations of molecular breeding paradigm.
- The project advanced the state of the art of chemical production in plants. FSL should determine if this pathway will be continued in the future.
- Great project and ideas. Overly achieving objectives. Disappointed not to see some of the technologies moving forward.
- This seems like a good time to end this project. Laboratory experiments were informative; however, it does not seem like this is a promising avenue for co-product production that will help get the biofuel industry off the ground.
- This is a high risk/high reward project that was perhaps too ambitious. Some of the planned tasks were dropped because of lack of adequate progress. For those tasks completed, achievements relative to the critical success factors was minimal, and the project contractor has abandoned any work with biomass feedstocks. Advances in genetic manipulation that may be significant in other applications were accomplished, but the value to BETO was minimal. Greater integration with other projects addressing the bio-factory concept was needed.
- Overall, the project has successfully demonstrated that the genomics may be a path toward failure for successful establishment of bioenergy industries in the United States. The project could not overcome all technical barriers related to efficient extraction of biopolymer from plant biomass in order to be economically successful in the near future. However, the technical advancements related to genomics of energy crops are innovative and could be adapted by other food/feed or pharma industries.

PI Response to Reviewer Comments

- No official response provided at time of report publication.

BIOMASS ENGINEERING

(WBS#: 1.2.1.1)

Project Description

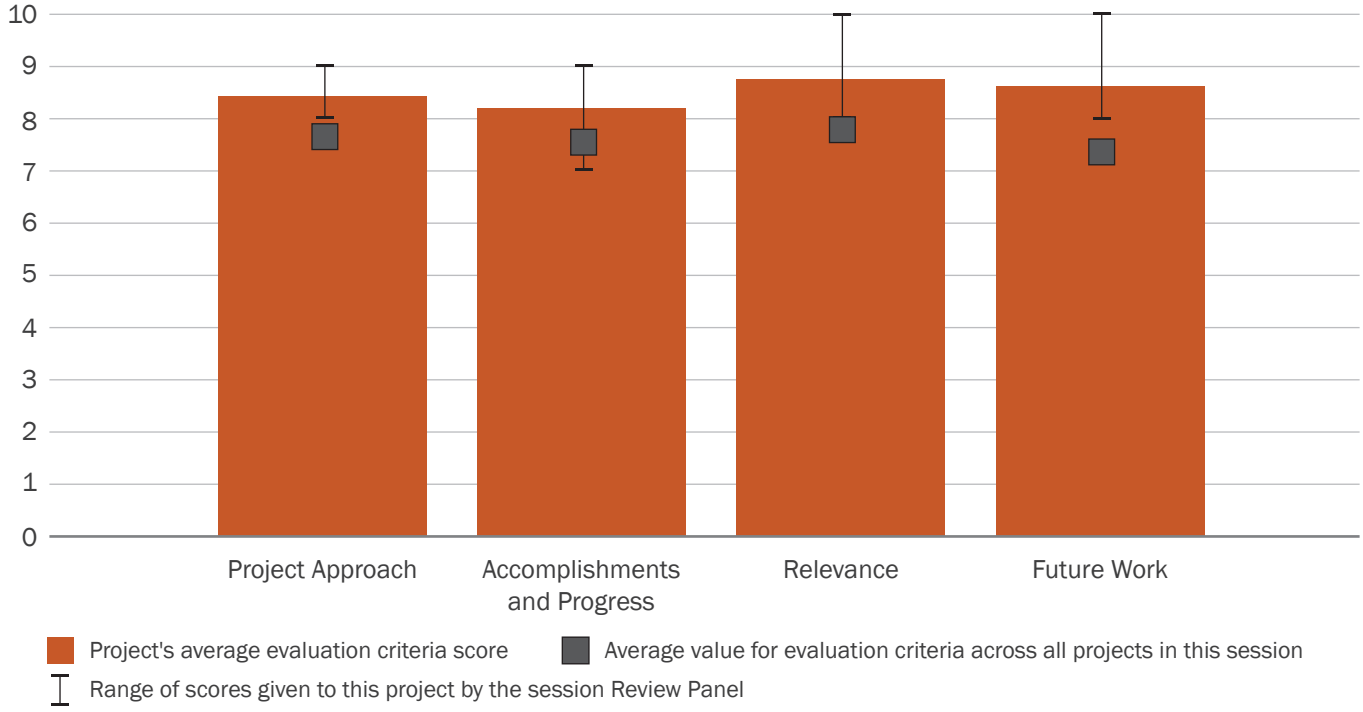
Results from the current integrated biorefineries and prior research at INL have demonstrated the negative impact of moisture and soil content in baled biomass. Impacts include biological degradation, displacement of valuable carbohydrate by soil, and increased preprocessing and handling costs for high-moisture and soil-laden biomass. Best management practices have gone only so far in reducing the bale-to-bale variations in moisture and ash seen in commercially harvested stover. Active management is needed to further reduce these unwanted variations. Timely information is necessary to make decisions that impact moisture and soil content during harvest and to deliver biomass to the biorefinery in a way that reduces day-to-day variations that affect preprocessing and conversion operations.

Recipient:	Idaho National Laboratory
Principal Investigator:	Bill Smith
Project Dates:	10/1/2006–9/30/2017
Project Category:	Ongoing
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$1,100,000
DOE Funding FY 2015:	$1,185,000
DOE Funding FY 2016:	$1,190,000
DOE Funding FY 2017:	$1,190,000

This project will identify and adapt robust analytical tools to evaluate moisture and soil content in baled stover and provide a coarse measurement that enables harvesters to reduce soil contamination. The project will also allow biorefineries to schedule delivery of biomass of known moisture and soil content to blend the highs and lows and reduce daily variations at the plant. By 2018, the project team aims to accomplish the following goals: (1) demonstrate in-field and on-equipment tools to measure and reduce soil contamination in stover bales, and (2) produce an example of an actively

Weighted Project Score: 8.5

Weighting: For ongoing projects, there is equal weighting across all four evaluation criteria: Approach, Relevance, Accomplishments and Progress, and Future Work.



Photos Courtesy of Idaho National Laboratory

managed queuing system that predicts dry matter loss and moisture content in stacked stover bales based on storage method and ambient weather conditions.

Overall Impressions

- This is a very practical project that directly addresses the information needs of biorefineries. It can directly reduce risk for the pioneer cellulosic ethanol biorefineries. Good collaboration with industry. Would like to see how this corn stover work supports other feedstocks.
- This work is essential to advance the state of the art and optimize the harvesting and storage of biomass to increase the quality and develop strategies to lower the ash and moisture content of the biomass.
- Great approach for having *in-situ* NIR technologies. Research work is valuable for developing new and improved methodologies for measuring ash, sugars in biomass during harvesting and storage to monitor biomass quality.
- Excellent project trying to tackle a complicated issue using the expertise of national laboratory and industry partners.
- The development and advancement of sensing technologies for biomass quality assessment is needed for the developing biofuels industry. It is clear that the ability to accurately assess the quality of biomass will be needed to support an efficient market that can establish prices based on quantity and quality, as well as process control needed in biorefineries. To date, the project has focused on corn stover.

  As the project moves forward, it should incorporate other feedstock types. A strong understanding of the influences of biomass species and variety, maturity level, and harvest methods on the accuracy of NIR measurements of moisture, ash, and other quality parameters is needed. As would be appropriate for any project on assessing quality parameters, both accuracy and repeatability of the estimates must be determined and reported. Models developed should have as outputs both a best estimate and the uncertainty level of that assessment.
- Overall, the project has highlighted technical challenges with the existing feedstock delivery system affecting the biomass quality and its implication to downstream conversion processes. The project has made significant progresses to address major technical issues. The project should consider developing best management practices that preserve the quality of biomass feedstock that can be delivered to a biorefinery for smooth operation.

PI Response to Reviewer Comments

- The project team thanks the reviewers for their encouraging and constructive feedback. Several topics received multiple reviewer comments, such as establishing best management practices, analysis validation at commercial sites and scale, and evaluation of biomass resources beyond corn stover. This task has evolved since its inception from evaluating existing harvest and collection systems and practices to efficiently meet corn stover and other biomass supply quantities and costs (FY 2011–FY 2013), to quantifying the economic impact of important qualities such as moisture and ash content early in the supply chain (FY 2015), and recently has focused on methods to detect moisture and ash in baled biomass prior to delivery.

  Our experience is that passive efforts such as best management practices have gone only so far toward reducing problems associated with ash (soil contamination) in harvest and moisture (dry matter loss) in storage. We believe that active management early in the supply chain is needed to address the immediate problems of moisture and ash. Active management requires rapid evaluation and access to the results in time to change the process—harvest, baling, or storage—to preserve the biomass' inherent value to the end user. These rapid methods need to balance accuracy with speed, sensitivity with value, and do so with equipment and methods that are sufficiently robust to withstand use in a commercial biomass supply chain.

  Our 1st-year efforts have been to select a subset of existing analytical methods to extend into the field. As we down-select we will, as the reviewers suggest, evaluate the accuracy and repeatability of these methods first in the laboratory and later in commercially-relevant conditions. Our work has started with corn stover for several reasons, including the following: (1) current integrated biorefineries rely on this resource; (2) it is abundant and makes up a large portion of the available herbaceous biomass in the United States now and into the future; and (3) it typifies the industry's current problems related to ash/soil contamination during harvest, material losses related to storage moisture, and biomass variability (moisture, ash, and carbohydrates) as it relates to industrial scale preprocessing and conversion. Ultimately, we will extend these methods—where applicable, as not all resources have the same quality-related challenges—to other biomass resources in the future.

DEVELOPMENT OF A WET LOGISTICS SYSTEM FOR BULK CORN STOVER

(WBS#: 1.2.1.1000)

Recipient:	Idaho National Laboratory
Principal Investigator:	Lynn Wendt
Project Dates:	10/1/2015–9/30/2017
Project Category:	Ongoing
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$0
DOE Funding FY 2015:	$535,000
DOE Funding FY 2016:	$667,250
DOE Funding FY 2017:	$385,000

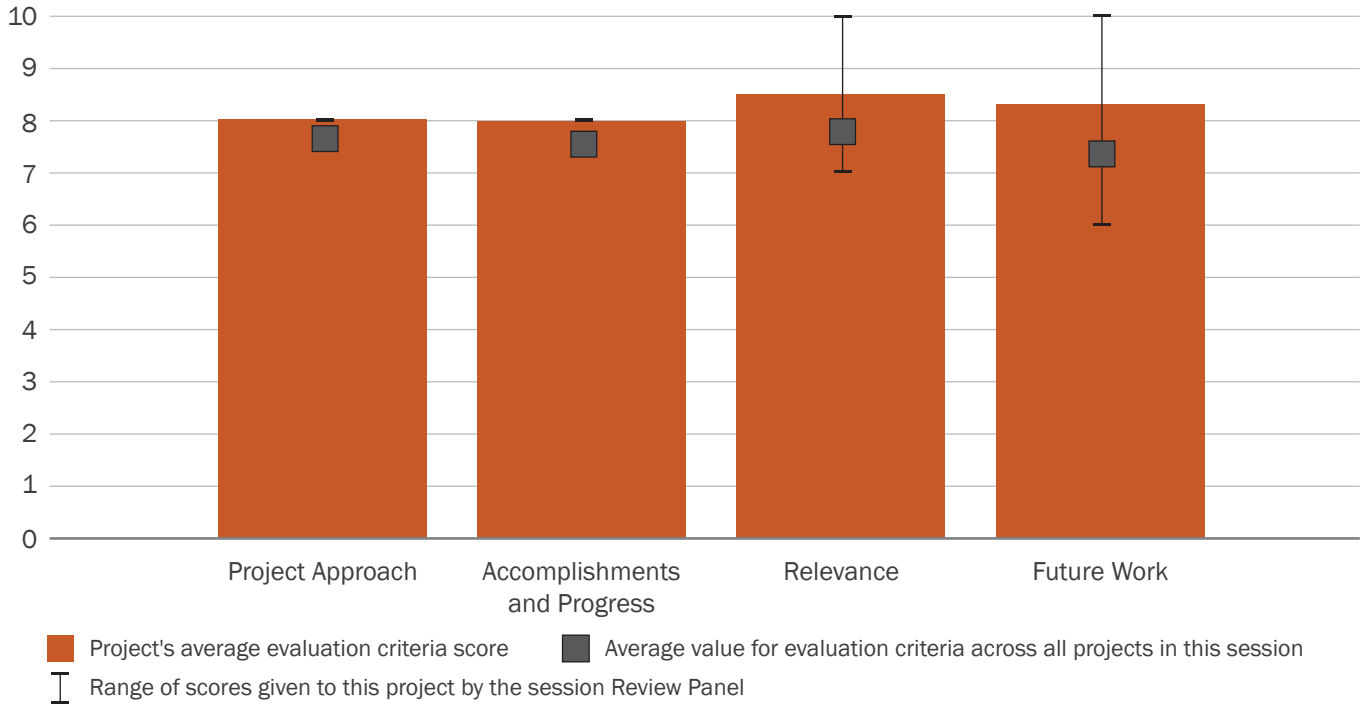
Project Description

This project evaluates centrally located wet biomass storage and the enabling logistics operations at an industrial scale to control logistics costs, preserve feedstock value in wet climates, and reduce the risk of fire. This project also enables mobilization of the high-moisture portions of the nation's billion tons of biomass, which includes over 50% of available corn stover. The technical approach is based on TEA of the wet logistics system through (1) harvest, collection, and transportation costs obtained using the INL Biomass Logistics Model; (2) an engineering design detailing unit operations and associated costs of large scale biomass storage at a refinery gate; and (3) laboratory storage performance for two wet storage approaches, industrial-scale ensiling, and modified Ritter storage.

A go/no-go decision based on TEAs selected industrial-scale ensiling as cost competitive with the 2015 target for three-pass stover in a dry system. A field demonstration of anaerobic storage for wet corn stover was completed in coordination with an industrial partner. Corn stover (40% moisture) was harvested using common forage industry methods, and a 300-dry ton drive-over pile was constructed, covered, and stored for 6 months. Dry matter loss averaged <5%, compared to the target

Weighted Project Score: 8.2

Weighting: For ongoing projects, there is equal weighting across all four evaluation criteria: Approach, Relevance, Accomplishments and Progress, and Future Work.



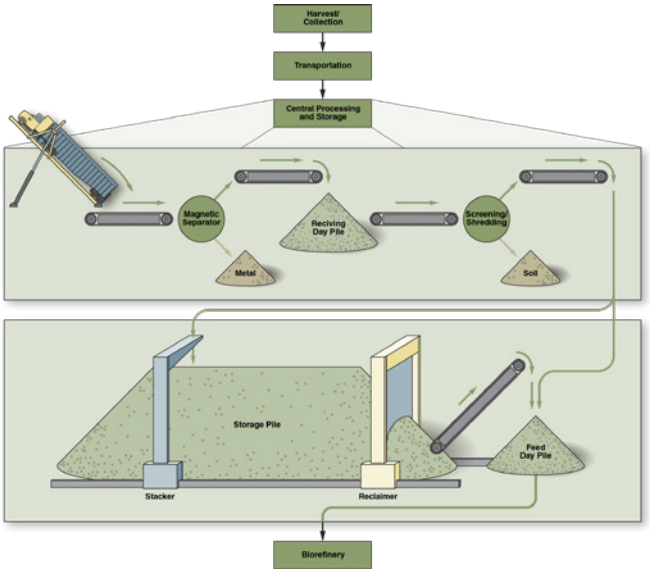


Photo Courtesy of Idaho National Laboratory

of 12% loss for corn stover in the dry logistics system. This work has successfully developed a cost-competitive logistics system for high moisture corn stover.

Overall Impressions

- Overall, this project is addressing baseline performance of wet storage, and has identified metrics to assess and choose wet storage methods. The work is useful and future work is on target, assessing biomass sorghum where this system is likely to be more advantageous than in corn stover.
- Project team needs to define safety risks associated with such systems, perform social-economic impact analysis, and integrate work with USDA. Great collaboration with national laboratories.
- This is an innovative project with many results comparing cost, water use, and energy use of wet and dry storage of stover. Well done. It would be really interesting to expand this project to include other feedstocks expected to have high moisture content for at least the techno-economic analysis.
- The examination of storage methods for wet biomass is a response to a suggestion in a previous project evaluation of a gap in BETO strategies, and a recognition that a significant portion of the billion-ton biomass requirement result in material collected at moisture levels above 20%. This will be especially true for biomass sorghum and energy cane. The examination of alternative methods and identification of the superior choice between the two alternatives examined represents significant progress. Further study is needed to get the costs down to make the system competitive with baling systems.

  This project is contributing to BETO goals and should be continued. Future work should include expanding the number of crops stored to determine if the approach is equally suitable for stover, sorghum, switchgrass, or energy cane. The high cost of transporting chopped material from the field to storage is well-known, so alternatives that minimize the distance traveled, or increase the density during transport should be considered. Alternative configuration for anaerobic storage might be considered. The potential for chemical pretreatment during the anaerobic storage should be examined. Comparison of alternatives should incorporate both the logistics costs and biomass quality change during storage. This project should be a part of the FCIC portfolio.
- The project is focused on investigating the technical feasibility of wet storage biomass system. It has demonstrated that the wet storage system has doubled the cost of a conventional storage system. Although the wet storage system has some cost and technical issues, the benefits to pretreatment of biomass should be identified. The project has some potential to de-risk feedstock deconstruction issues for the Biochemical Conversion R&D Technology Area.

PI Response to Reviewer Comments

- We thank the reviewers for the encouraging feedback regarding this work. The focused research on wet logistics systems for corn stover has shed light on multiple opportunities for additional cost reduction to consider in the future. We agree that wet logistics systems should be expanded to include energy crops, which are often harvested at moisture contents exceeding 50% (wet basis) and do not readily dry in the field, as in the case of biomass sorghum, or often need to be harvested earlier in the season at high moisture contents due to difficulties getting into the field in wet years, as can be the case with switchgrass. Energy crops have an advantage over corn stover in that they have high yields per harvested acre and would be able to fulfill the feedstock requirements for a biorefinery with a reduced draw radius compared to corn stover, resulting in reduced transportation distances and associated costs. Energy crops also present a challenge, as the soluble sugars at the time of harvest may be higher than corn stover, and these sugars must be preserved in order to contribute to biofuel production.
- We have demonstrated in this project, through laboratory and field studies, that wet, anaerobic storage can successfully preserve high moisture biomass. We will continue to look for ways to lower the costs of wet logistics systems so they are competitive with dry bale systems, for example by reducing transportation costs, preserving soluble and structural sugars in storage, and realizing the potential for pretreatment during wet storage.

SIZE REDUCTION, DRYING AND DENSIFICATION OF HIGH MOISTURE BIOMASS

(WBS#: 1.2.1.2)

Project Description

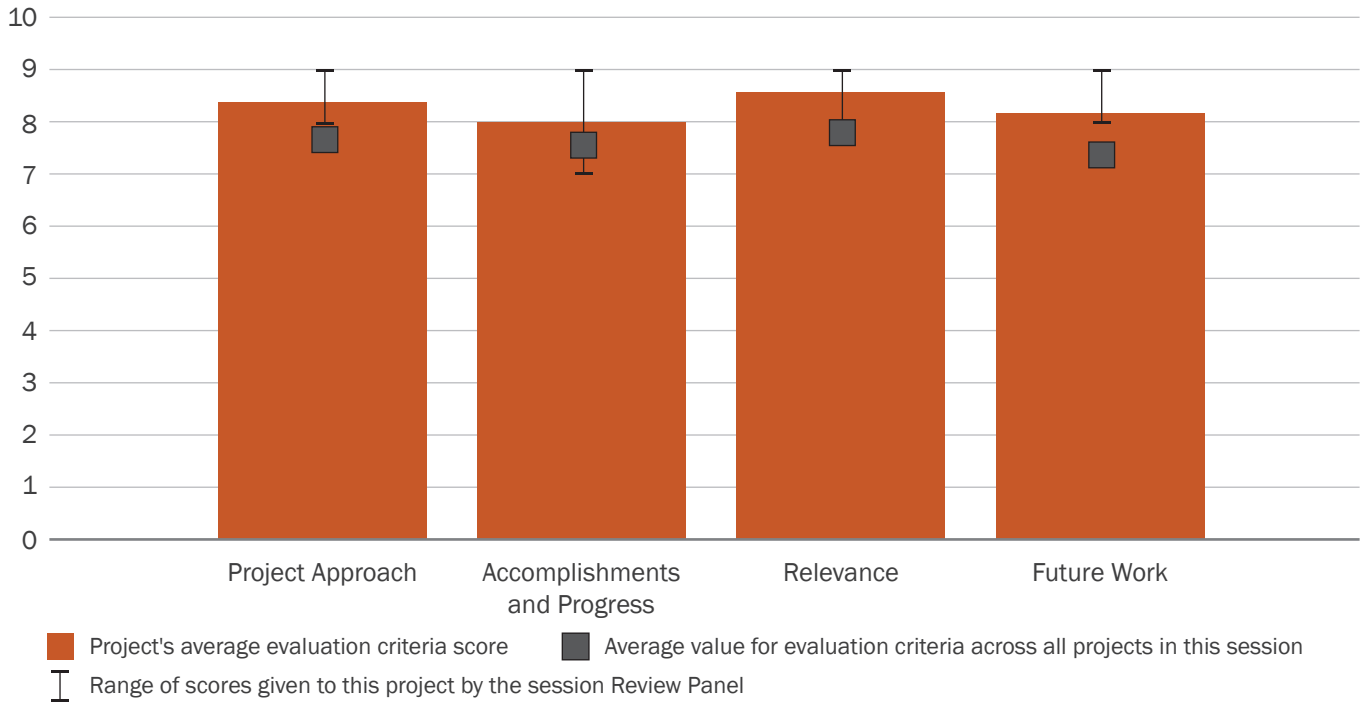
More than 50% of the biomass in the United States is at moistures >30% (weight basis). High preprocessing costs and poor flow properties limit their use for biofuels production. Developing cost-effective solutions is critical to utilize these biomasses for biofuel production. The goal of this project is to reduce preprocessing costs by 50% compared to the 2013 SOT and support the DOE feedstock cost of $84 /dry ton. Our technical approach uses fractional milling, high moisture pelleting process, and low temperature drying to reduce the preprocessing cost. In fractional milling, bigger screens are used in the stage-1 grinder, and a separator is inserted between stage-1 and 2 grinders to bypass the fraction that has met the specification.

Recipient:	Idaho National Laboratory
Principal Investigator:	Jaya Tumuluru
Project Dates:	10/1/2015–9/30/2017
Project Category:	Ongoing
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$1,500,000
DOE Funding FY 2015:	$1,450,000
DOE Funding FY 2016:	$1,232,500
DOE Funding FY 2017:	$1,232,500

FY 2016 studies reduced the grinding costs to $14.5/ dry ton for 0.25-inch screen size specification. In high moisture pelleting, biomass is pelleted at moistures >20%. The major advantage is that biomass loses some moisture due to heat generated in the pellet die, and the high moisture pellets produced can be dried using grain dryer. In FY 2016 high moisture pelleting was demonstrated on pilot-scale ring die pellet mill and pellet density and durability targets (>480 kg/m3 and >95 %) were met. Fractional milling and high moisture pelleting resulted in about 17% moisture losses in the biomass. Based on TEA, the cost to pelletize corn stover is reduced to

Weighted Project Score: 8.3

Weighting: For ongoing projects, there is equal weighting across all four evaluation criteria: Approach, Relevance, Accomplishments and Progress, and Future Work.



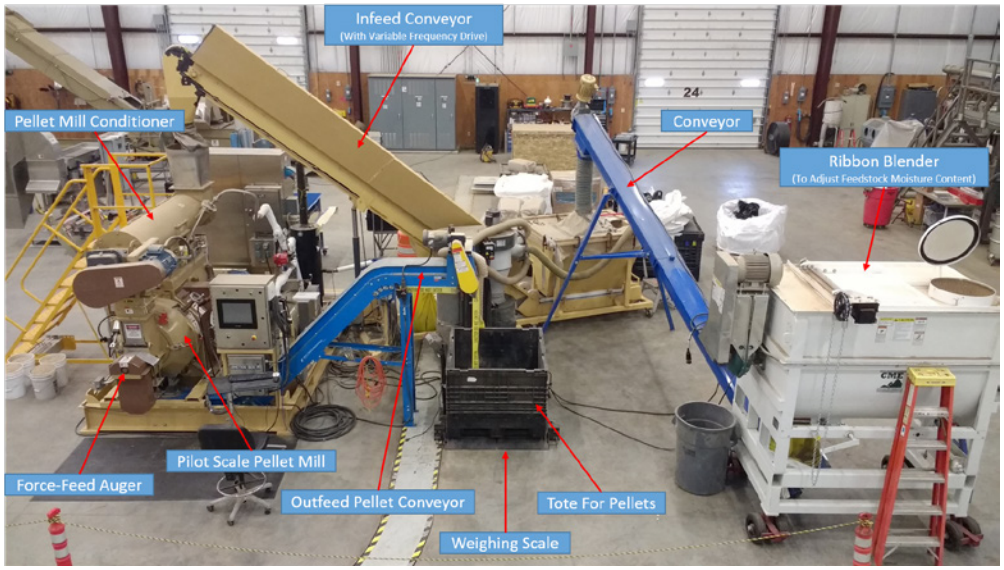


Photo Courtesy of Idaho National Laboratory

$25.35/ dry ton, this is lower than the cost established for a 1-inch grind ($25.67/ dry ton).

Overall Impressions

- My overall impressions of this work are that it provides predictive relationships that enable pelleting of higher moisture biomass while minimizing energy use and cost. Publicly available information supports the industry and saves them costly trial and error.
- The trade-offs of pelletization should be clearly defined to establish the viability of the concept on different conversion processes and biomass types. The benefits are dependent on the conversion process and the type of biomass.
- Great to see cost reduction. However, process evaluation with other feedstock materials/blended materials (higher lignin content, ash content) is needed.
- This is a good project with lots of results and progress made to meet preprocessing price reduction goals. However, this is an existing process used in forestry therefore it isn't really new technology. Please clearly explain the limits to cost reduction if new technology is not developed and this framework continues.
- Examination of the potential for pelleting high moisture biomass is part of the BETO strategy of developing pathways for handling feedstocks as they are available from the field. This project has made considerable progress on evaluating SOT for pelletizing high moisture feedstock. Significant energy savings over conventional pelleting operations were identified, but further validation of the claimed energy requirement in grinding high moisture feedstock using large screen-size is needed. The ability to store high moisture pellets without mold/fungal growth will need to be demonstrated. The project worked with reconditioned materials at 30% moisture. Real world situations will result in 30%–50% moisture material, so this project should expand the range of material (type, moisture level, quality) considered. This project addresses BETO's goals, and should be continued.

PI Response to Reviewer Comments

- This project has looked in understanding the effect of bigger screens in stage-1 and 2 grinders. The results indicated that a bigger screen size of 3 inches in Stage 1 and bigger screen size in Stage 2 (7/16 inch) using fractional milling has reduced the grinding energy by about 65% compared to conventional Stage 1 and Stage 2 grinding process fitted with 2-inch and ¼-inch screens. This will be verified in the integrated demonstration of the process at commercial scale, which is scheduled for September 2017.

- The high-moisture pelleting process tested in this project makes biomass drying optional. If the pellets have to be stored for a short time and be transported short distances drying can be avoided. If the pellets have to be stored for long durations and be transported to long distances, the low temperature drying technologies such as grain or belt dryer can be used to reduce the final moisture content of the pellets to <9% for safe storage to avoid mold or fungal growth.
- The studies on high moisture pelleting were done using reconditioned material and high-moisture bales. The trends observed for both the material in terms of product properties and energy consumption was similar.
- Our integrated design report[7] deals with biomass bales at 50% moisture content. The storage task (WBS: 1.2.1.1) work is focused on finding cost-effective means to deliver corn stover bales at a maximum moisture content of 30%, via storage conditions that actively or passively reduce the moisture content over time in storage. Therefore, in this project preprocessing has to deal with biomass bales at 30% moisture content.
- We have tested pellets in fast pyrolysis and biochemical conversion. This testing has identified that the fines generated during pelleting can be a problem. Future work is aimed to address this issue which will involve additional testing to understand the viability of the concept on different conversion processes and biomass types.
- Pelleting is not a new technology, but biorefineries are not ready to use the pelleting process currently used in the industry due to high preprocessing cost. In this project we developed a new method which operates at different process parameters, and order of unit operations to produce pellets. This new process was demonstrated at pilot scale (1 ton/hour). TEA of the new process developed indicated that the cost of pelleting is reduced by 62% compared to current technology,[8] which is commonly used in pellet industry.

[7] Kevin L. Kenney, Kara G. Cafferty, Jacob J. Jacobson, Ian J. Bonner, Garold L. Gresham, J. Richard Hess, Leslie P. Ovard, et al., Feedstock Supply System Design and Economics for Conversion of Sugars to Hydrocarbons, (Idaho Falls, ID: Idaho National Laboratory, September 2013), INL/EXT-13-30342, https://bioenergy.inl.gov/Reports/Design%20Case%202017.pdf.

[8] Patrick Lamers, Mohammad S. Roni, Jaya S. Tumuluru, Jacob J. Jacobson, Kara G. Cafferty, Jason K. Hansen, Kevin Kenney, Farzaneh Teymouri, and Bryan Bals, "Techno-Economic Analysis of Decentralized Biomass Processing Depots," *Bioresource Technology* 194 (2015): 205–213, https://doi.org/10.1016/j.biortech.2015.07.009.

RESOURCE MOBILIZATION

(WBS#: 1.2.1.5)

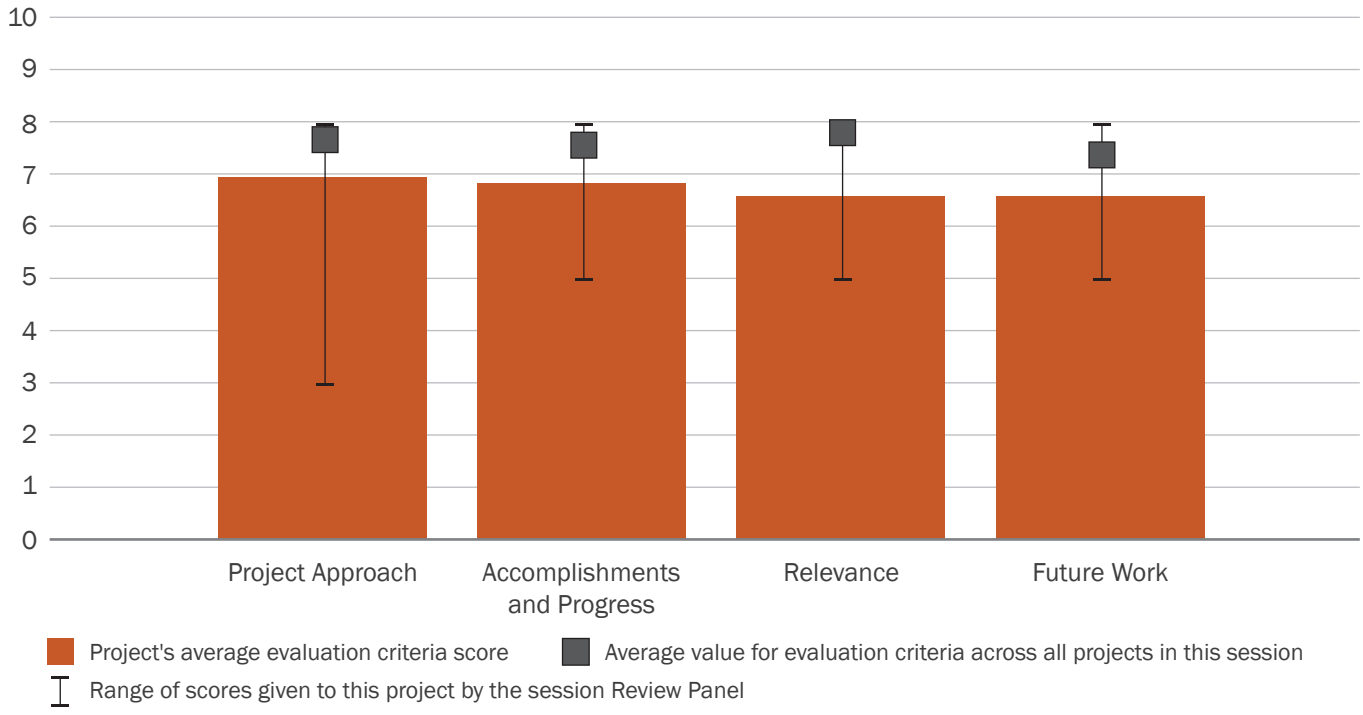
Recipient:	Idaho National Laboratory
Principal Investigator:	Patrick Lamers
Project Dates:	1/25/2010–9/30/2017
Project Category:	Ongoing
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$160,000
DOE Funding FY 2015:	$255,000
DOE Funding FY 2016:	$255,000
DOE Funding FY 2017:	$255,000

Project Description

This project investigates the dynamics and growth opportunities in current and emerging U.S. feedstock markets via business-to-business market information and econometric analysis to identify pathways for biomass resource mobilization. As U.S. biofuels industry representatives concluded in a DOE workshop, markets are a primary driver to enable a future billion-ton U.S. bioeconomy. In feedstock markets, processing is a requirement to achieve product fungibility. With the current lack of demand from U.S. biorefineries, alternative markets to biofuels, such as animal feed or biopower, are required to build out U.S. feedstock processing capacity, which increases the amount of resources available to the market. This increases supply security beyond individual farmer contracts, which, according to finance sector officials, is a prerequisite to access financing for conversion facilities. A specific focus of the project is to evaluate the risks and benefits commoditization and trade of domestic resources may have on future domestic supply quantities and prices. Leveraging existing modeling expertise at INL and collaborators at other U.S. national laboratories and partner universities, the project quantifies the impacts of current alternative and future competing feedstock uses to biofuels, supporting a respective BETO MYPP milestone. It also provides feedstock market intelligence to related BETO efforts (e.g., *BT16*, Biomass Scenario Model) to strengthen respective scenario developments.

Weighted Project Score: 6.8

Weighting: For ongoing projects, there is equal weighting across all four evaluation criteria: Approach, Relevance, Accomplishments and Progress, and Future Work.



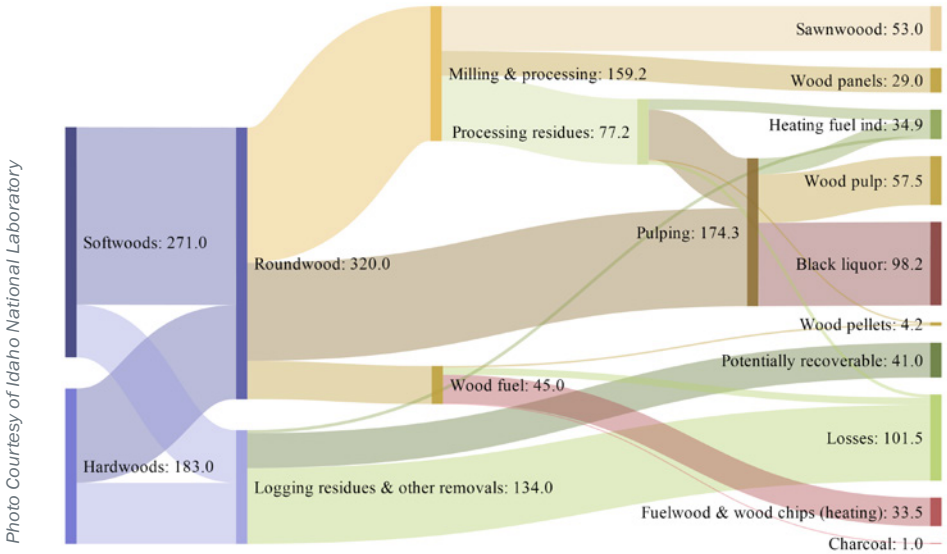


Photo Courtesy of Idaho National Laboratory

Overall Impressions

- My overall impression is one of confusion. I suggest in the future trying to use some concrete examples to explain approach and results. I learned more from the questions from reviewers when the presenter gave explicit examples than I did from the generalizations in the presentation.
- The project evaluates and provides information of a potential mature market. Its interesting work but of limited value.
- Strength: The potential domestic application of pellets into markets other than combustion.

  Weakness: The project needs to vertically integrate supply chain to market, and bring in other partners.
- There are lots of insights and informative results presented here. All future work focuses on developing models with more detail or additional model assumptions. It seems more relevant for future work to focus on additional herbaceous feedstocks and alternative markets.
- This project seems to meet an internal BETO need, and as such provides value. As an exercise to identify methods for minimizing risk in the developing biofuels industry, it can provide insight to possible directions of market development. Alternative markets for biomass feedstocks need to be examined more closely. Feedstocks grown for biomass have been selected for high productivity rather than palatability or nutrient content, and are likely not to be considered a high-quality animal feed. The project should consider near-/mid-term needs and the impact of vertical integration on the biomass market.
- Overall, the project has tried to identify issues related to market penetration of biomass products in the international market and solve issues raised from non-technical factors. However, the project should clearly state how the outcome of this project will directly impact BETO's goals and objectives.

PI Response to Reviewer Comments

- This project directly supports the BETO MYPP Milestone: "by 2017, determine the impact of competing uses and policy and market demands (e.g., biopower or pellet exports) on feedstock supply and price projections." It also indirectly supports BETO goals such as meeting a $84/dry ton cost target at the reactor throat by identifying pathways for biomass mobilization that leverage existing and emerging non-biofuel markets to spread investment costs (e.g., of preprocessing facilities such

as a pelleting depots) across multiple markets and products and as such helps reduce intermediate unit production costs. Identifying non-biofuel feedstock markets for growers and processers to sell into (and determining their price, volume, and time span) creates near-term commercialization strategies in the biomass market. This directly supports the BETO goal of mobilizing domestic resource to fuel a U.S. bioeconomy.

The project does not explicitly model a mature market. Rather it is focused on analyzing current biomass supply chain and market structures to lay out pathways for additional resource mobilization, which could support the nascent bioeconomy. As such, the project aims at providing transition strategies via meta-level market analysis. It is not aimed at solving technical issues of emerging integrated biorefinery operations. Rather, it is a means to supplement respective process solutions by market analysis on their scale-up and deployment potential.

Within the given budget only the most-promising biomass industries for near-term commercialization and feedstock supply have been investigated in detail. Across the last 2 years, this was foremost the U.S. wood pellet industry.

Future work aims at determining potential spill-over and learning curve effects from this industry to other markets, herbaceous biomass in particular. Also, the project will expand its supply chain analyses to include strategies and lessons learned from other industries (e.g., vertical and/or industrial integration). Less focus will be given to the development of new modeling capabilities. Rather, the next steps will be to integrate and connect this work to other modeling and analysis approaches across the FSL and Analysis and Sustainability Programs.

FEEDSTOCK SUPPLY MODELING

(WBS#: 1.2.3.1)

Project Description

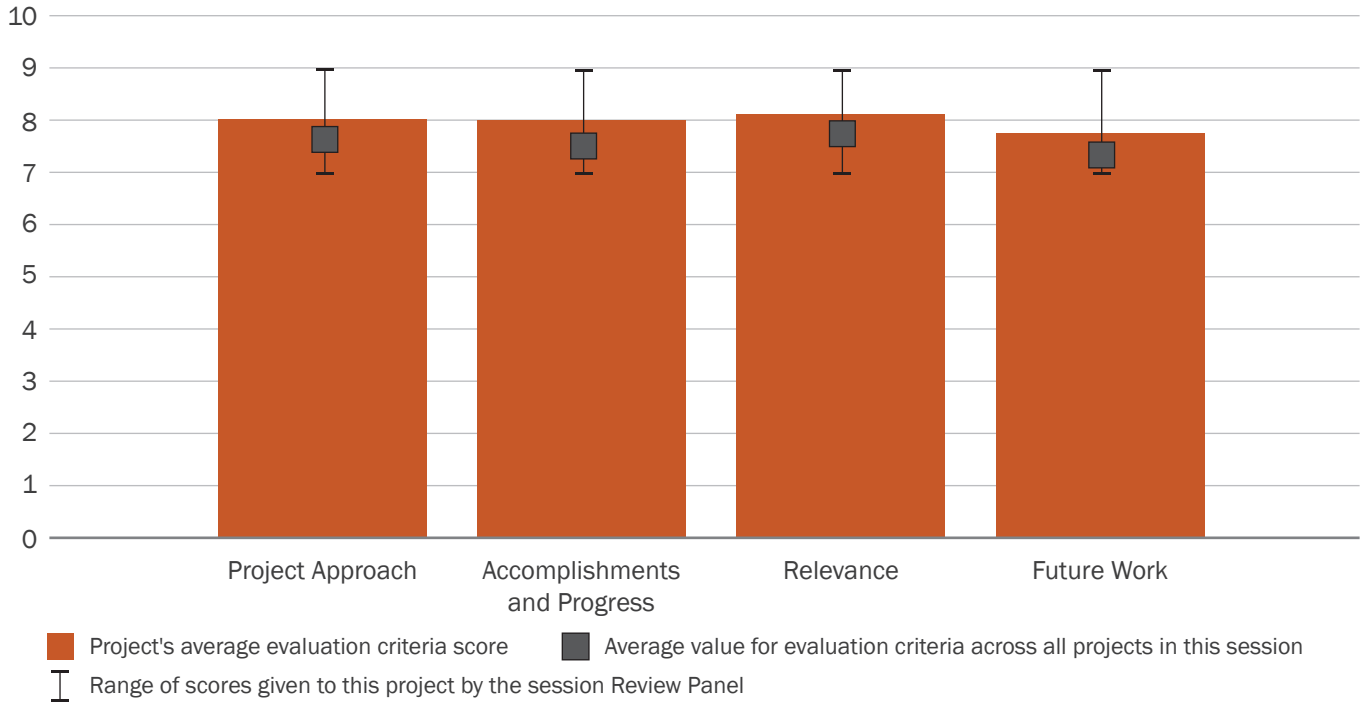
Simulation analyses of this project identify regional supply chain strategies to reliably and cost-effectively deliver consistent feedstocks for production of competitive biofuels and bioproducts using highly variable biomass resources. The Integrated Biomass Supply Analysis and Logistics Model, Supply Characterization Model, and advanced visualization tools have been integrated with biomass availability projections from the 1.1.1.1 Resource Assessment Project to (1) determine progress toward BETO feedstock cost and quantity targets, (2) model impacts of quality-improvement strategies along the supply chain, (3) estimate equipment and infrastructure needed for supplying biomass feedstocks, and (4) identify promising candidate feedstock blends for experimental testing.

Recipient:	Oak Ridge National Laboratory
Principal Investigator:	Erin Webb
Project Dates:	10/1/2005–9/30/2018
Project Category:	Ongoing
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$300,000
DOE Funding FY 2015:	$1,050,000
DOE Funding FY 2016:	$1,050,000
DOE Funding FY 2017:	$950,000

Applying simulation tools across the supply chain can help develop strategies to avoid the system inefficiencies that can occur when component technologies are blindly selected without consideration of how they impact or are affected by other supply chain design decisions. Accomplishments in this project include the following: development of an algae biomass supply chain model, new analysis of corn stover field drying potential across the United States, and expanding the Billion-Ton projections to include cost delivered to the reactor throat.

Weighted Project Score: 8.0

Weighting: For ongoing projects, there is equal weighting across all four evaluation criteria: Approach, Relevance, Accomplishments and Progress, and Future Work.



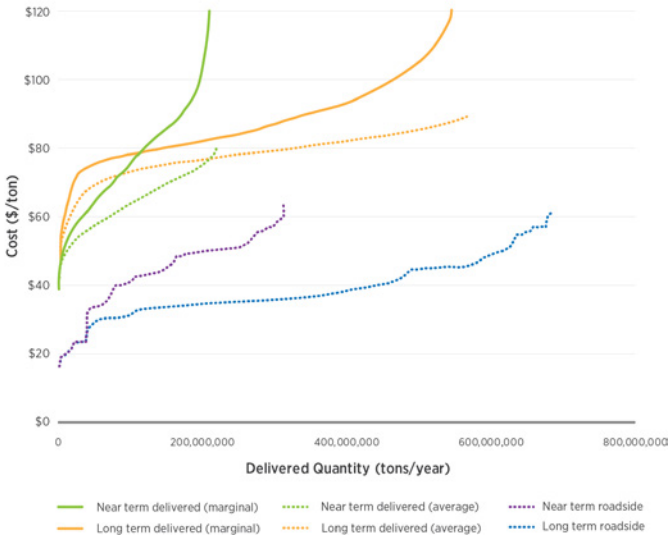


Photo Courtesy of Oak Ridge National Laboratory

Overall Impressions

- This is a high-impact, high-quality project that provides useful, realistic information on feedstock supply. It is well-integrated with commercial and sustainability aspects of the BETO portfolio.
- This is excellent work to estimate the potential and growth of the industry.
- This project has presented useful research. However, there needs to be integration with agencies, universities, and industry. The project needs to validate simulations with real data. The project should put more emphasis on the near term (e.g., the next 5 years) and less on the long term (e.g., 15–20 years).
- This project has accomplished a lot with its integrated modeling work; however, these studies seem disjointed and it is not clear if data are available to validate these complex processes.
- This project utilizes best available information from BETO and other biomass logistics projects to conduct a systems analysis of the supply chains and associated biorefineries. These efforts are closely linked to and support the *BT16* estimations of biomass availability. Technical accomplishments include the prediction of available biomass quantities at varying costs and the resulting number of biorefineries. The assumptions made are obviously overly optimistic, as a projection of 73 biorefineries in 2017 was shown, when we actually have two. Methodologies to benchmark and adjust predictions with current conditions should be considered.

  The work presented and the future activities effectively utilize expertise in the national laboratories, particularly Oak Ridge National Laboratory and INL. The planned work on modeling of biomass moisture management should be closely aligned with the efforts at INL to consider the storage and processing of high moisture materials. This project makes valuable contributions to BETO.
- Overall, the project has developed and integrated field drying modeling into the FSL model to manage and monitor the moisture content of delivered feedstock. It is expected that the future work will include additional feedstock quality specifications explicit to a biorefinery for accurately estimating the feedstock cost, while minimizing the feedstock quality risks.

PI Response to Reviewer Comments

- In the last 2 years, the Oak Ridge National Laboratory logistics modeling team have been working with their industrial partners to collect field data such as equipment speed, fuel consumption, bale bulk density, and harvest moisture content, etc. These models currently have updated input data. New harvest data were collected from biomass producers, aggregators, and equipment manufacturers (i.e., local farmers, State University of New York harvest team in New York and Oregon, Antares, Pacific Ag, and AGCO Corporation).

DESIGN AND DEMONSTRATION OF AN ADVANCED AGRICULTURAL FEEDSTOCK SUPPLY SYSTEM FOR LIGNOCELLULOSIC BIOENERGY PRODUCTION

(WBS#: 1.2.3.101)

Recipient:	FDC Enterprises Inc. (FDCE)
Principal Investigator:	Fred D. Circle
Project Dates:	9/1/2010–6/30/2015
Project Category:	Sun-setting
Project Type:	FY 2009—Feedstock Logistics: DE-FOA-0000060
Total DOE Funding:	$4,991,934
Project Dates:	2007-2014

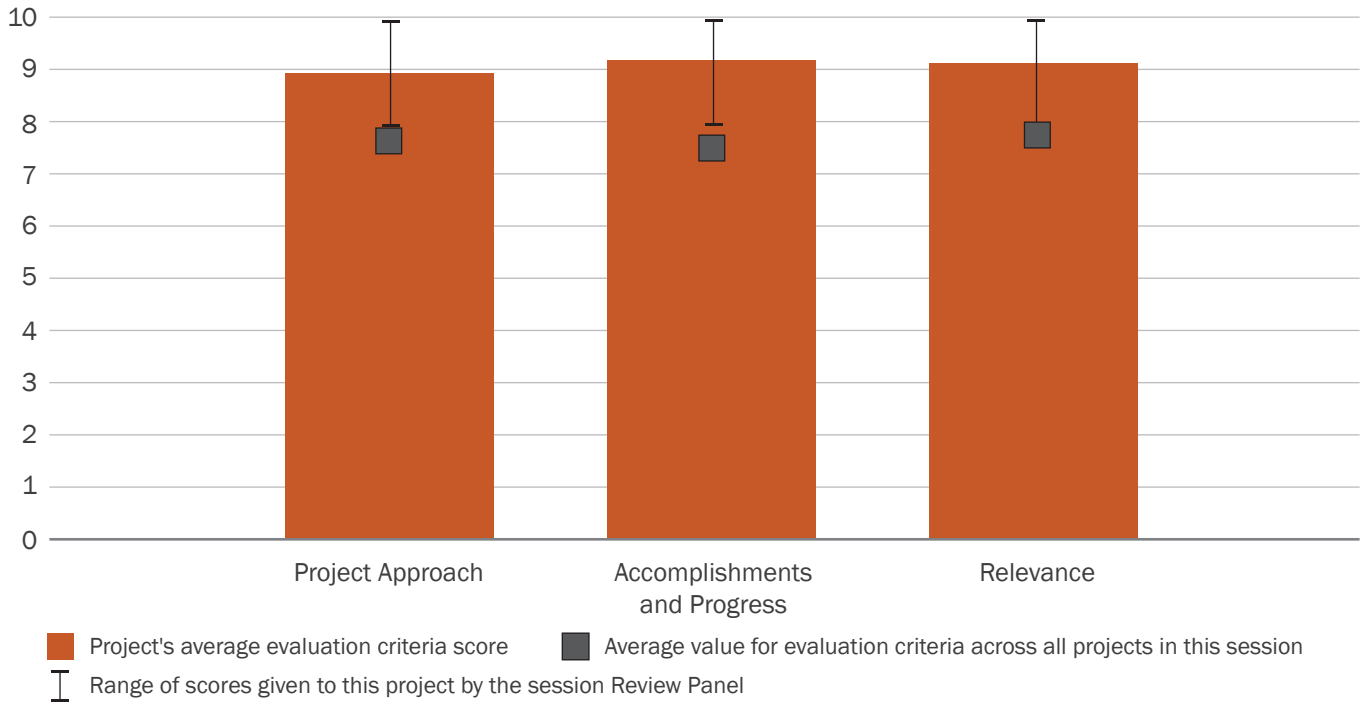
Project Description

This nearly-completed 3-year project developed and demonstrated four innovative, first-of-their-kind pieces of equipment that are aimed at significantly reducing the cost of delivered herbaceous biomass. This equipment included a Self-Propelled Baler (SPB), a Bale Picking Truck (BPT), a Self-Loading Trailer (SLT), and a Heavy Crop Header for harvesting high-yielding energy crops. This equipment was designed and fabricated during the first 2 years of the project and demonstrated on available crops (corn stover, wheat straw, and warm season grasses) across the nation, as available.

Operational performance and cost data were collected and analyzed throughout the project to measure the costs of baseline harvesting (using conventional harvesting equipment) and advanced harvesting with the newly developed equipment. These data revealed that the project met its original goal of developing equipment that is realistically capable of reducing the cost of delivered biomass by $13 per dry ton. Each machine was tested after fabrication and put to the test in one or more commercial harvesting seasons. During these tests, operational flaws were found and fixed through upgrades and improvements. The first new SPB, BPT,

Weighted Project Score: 9.2

Weighting: Approach–25%; Relevance–25%; Accomplishments and Progress–50%.



and two new SLTs were ready for use during the 2013 harvest season. Since then, over 40 SLTs have been ordered and are currently under fabrication. All of the equipment will be commercially available to the industry as demand increases.

Overall Impressions

- This was a very useful project that provided enabling experience, data, and equipment designs for the biomass industry, thus reducing commercial supply chain risk.
- This was an excellent project that provided a significant amount of industrial relevant data for the development and validation of industrial collection, harvesting, storage, and transport systems.
- This shows great improvements in bale transportation (e.g., more efficient and fast delivery, and direct feed into feed line). However, efforts in improving equipment for the efficient transportation of energy crops (e.g., sorghum or energy cane) are also needed. Separation of seed heads from stalks in the case of sorghum. Impact of harvesting equipment on biomass quality (e.g., ash or trash content) is needed. Overall, great project and execution.
- This project successfully developed and tested four new machines in 3 years that reduce cost by $13/dry ton. Well done.
- This was a report of the FY 2009 High Tonnage projects by FDCE. This project must be viewed as a major success. Each of the proposed machines was developed, and evaluations have occurred over 15,000+ acres, providing confidence in the reported results. The results to date have been reduced cost to deliver biomass, innovation in the development of new machines that reduce cost/increase capacity, and commercialization of some of those machines in related industries. The Integrated Biomass Supply Analysis and Logistics Model modeled cost for the full system showed a significant cost reduction, which was the primary goal of the project. This completed project provided significant innovation and directly addressed BETO goals.
- Overall, this project has accomplished all major challenges associated with collection, harvesting, storage, and transport of biomass bales using an integrated approach. The design innovation on the mobile floor trucking system is a major significant improvement to facilitate back-hauling capabilities.

PI Response to Reviewer Comments

- To the greatest extent possible, our team will continue our efforts to test and demonstrate the equipment innovations, where applicable, in crops other than corn stover. Our team has access to a 600-acre farm of high-yielding switchgrass and we will test as many pieces of equipment as possible as part of our annual harvest operations on that farm and elsewhere. We will also include biomass quality measurements as part of those efforts this will be much more affordable and practical now that we have developed the NIR bale probe that facilitates accurate and rapid measurement of key bale quality parameters.
- While one of our primary overall project objectives is to demonstrate innovative means of minimizing feedstock supply costs, our project team has been most focused on defining measurable technical goals and then measuring our performance against those goals for each piece of equipment our team members have developed and tested. Several performance targets were presented in the review presentation: (1) developing a self-unloading truck that can unload a full load of bales in less than 5 minutes; (2) developing a windrow merger that is capable of collecting two windrows of corn stover or perennial grass in a single pass through the field; (3) developing a bale gathering machine that can gather a full

truckload of bales (36) in each trip to the field; (4) increasing round bale density by more than 10%; 5) increasing round baler field efficiency by more than 50%; (6) developing a bale accumulator that can stack and drop six square bales at a time at each drop location in the field; (7) developing a square bale de-stacking machine that can reliably de-stack a 2 wide x 3 high stack of bales into a single line of bales for feeding a grinding line; (8) developing an automated round bale infeed line that can automatically remove net wrap and de-bale round bales for feeding into a grinding line; (9) developing a round bale hauling and unloading system that enables rapid high-volume unloading of round bales (20 bales in less than 10 minutes, including automated unloading onto a grinding line; and (10) developing a field-deployable NIR bale probe that can accurately and rapidly measure moisture, ash, glucan, and xylan content in biomass bales.

- Our team has gone to great lengths to document and measure all performance targets and other factors that will impact operational costs and functional value of each innovation our team members are developing. We have built an extensive database of harvest performance data, including results from harvest operations on over 30,000 acres of herbaceous biomass. This database includes labor, fuel, supplies, and maintenance costs for each harvested field. This and other performance data and results are periodically shared with DOE national laboratories (e.g., Oak Ridge National Laboratory and INL) for independent analysis and reporting. A similar approach has been and will (in future testing) be utilized for all process-related testing (bale handling, conveying, grinding, etc.) our team conducts. These results have and will include (wherever possible) efficiency improvements, productivity improvements, labor requirement reductions, fuel reductions, electricity reductions, cost impacts, and biomass quality measurements, etc.

DEMONSTRATION OF AN ADVANCED SUPPLY CHAIN FOR LOWER COST, HIGHER QUALITY BIOMASS FEEDSTOCK DELIVERY

(WBS#: 1.2.3.106)

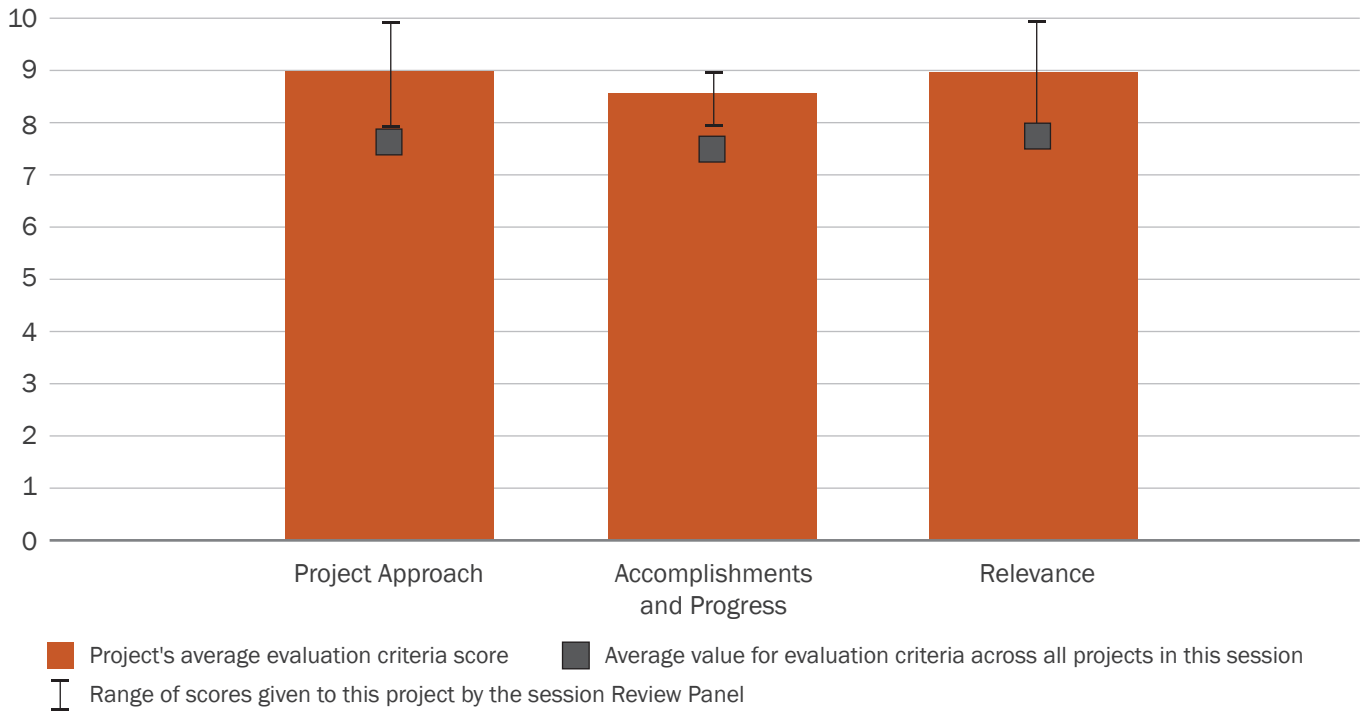
Recipient:	FDC Enterprises
Principal Investigator:	Fred Circle
Project Dates:	9/15/2013–9/30/2017
Project Category:	Sun-setting
Project Type:	FY 2013—Advanced Biomass Feedstock Logistics Systems II (Logistics II): DE-FOA-0000836
Total DOE Funding:	$5,250,000
Project Dates:	2006-2017

Project Description

This project will demonstrate an advanced biomass supply chain for high-impact, high-quality feedstocks from the field to the throat of a biorefinery. In doing so, the project will address nearly all of the technical barriers by BETO's FSL Program. The project builds on the earlier innovations of team members to reduce feedstock costs. This work highlights key gaps throughout the supply chain where biomass harvesting and processing costs could be further decreased while maintaining the end user's feedstock quality specifications. This effort includes designing and deploying new systems for end-use processing (e.g., new milling equipment, advanced bale handling, NIR monitoring and sampling, etc.), further refining feedstock production equipment developed and demonstrated under prior efforts and testing by this and other project teams, and demonstrating new feedstock harvest and logistics equipment. Importantly, this includes development of equipment and processes to provide biorefiners and harvesters the flexibility to produce and use round and/or square bales more efficiently and cos-effectively than is possible using today's "off the shelf" conventional equipment. To date, the

Weighted Project Score: 6.8

Weighting: Approach–25%; Relevance–25%; Accomplishments and Progress–50%.



project has designed, fabricated, and tested many new equipment innovations, conducted commercial-scale biomass harvest demonstrations, tested new methods for analyzing biomass feedstocks with NIR, and assessed soil sustainability impacts.

Overall Impressions

- This is an important project for developing the equipment, analytical techniques, and workforce for the biomass industry. Project results have been rapid and impactful to industry partners.
- This project is well on its way to meeting the needs of the industry in the near to mid-term to lower the cost of the collection, harvesting, storage, and transport supply system. The team has a very good understanding of the needs of the industry and the systems required to lower the biomass supply cost.
- Great presentation, met all objectives mentioned, resulted in the development/improvement of equipment (prototypes) that will improve biomass quality, reduce harvesting cost. I would like to see the same approach on other feedstocks (energy crops).
- The team did a good job identifying and filling gaps in equipment supply chain to reduce cost.
- This was a report of the FY 2013 high tonnage projects by FDCE. The team of industrial partners from FY 2009 was successful enough that additional partners asked to join the FY 2013 project with no funding, a clear sign of impact for the project. The inclusion of an optimized system that would accommodate round bales, used in the smaller farm operations of the eastern states, is an expansion of the original project concept and potentially expands the portions of the United States where biofuels industries might be sited.

  Suggestions for enhancing the value of this project during the remaining years include emphasizing the operation over a larger range of biomass crops (the great majority to date has been corn stover), and the incorporation of delivered biomass quality into the evaluations of the systems. The FY 2013 funding did require quality assessment, and the NIR work reported does address that aspect. However, the project is urged to include those quality measurements into their assessments of the system performance.
- Overall, the project is directed right on the target and made considerable progresses to find solutions to technical barriers on handling round and square bales. A number of innovative technologies were developed in an attempt to successfully handle bales. The performance and cost targets will hopefully be addressed in order to meet the commercial viability and success of the project.

PI Response to Reviewer Comments

- Similar to the “Design and Demonstration of an Advanced Agricultural Feedstock Supply System for Lignocellulosic Bioenergy Production” project, our team will continue our efforts to test and demonstrate the equipment innovations, where applicable, in crops other than corn stover. Our team has access to a 600-acre farm of high-yielding switchgrass and we will test as many pieces of equipment as possible as part of our annual harvest operations on that farm and elsewhere. We will also include biomass quality measurements as part of those efforts--this will be much more affordable and practical now that we have developed the NIR bale probe that facilitates accurate and rapid measurement of key bale quality parameters.

  While one of our primary overall project objectives is to demonstrate innovative means of minimizing feedstock supply costs, our project team has been most focused on defining measurable technical goals and then measuring our performance against those goals for each piece of equipment our team members have developed and tested.

Several performance targets were presented in the review presentation, including the following: (1) developing a self-unloading truck that can unload a full load of bales in less than 5 minutes; (2) developing a windrow merger that is capable of collecting two windrows of corn stover or perennial grass in a single pass through the field; (3) developing a bale gathering machine that can gather a full truckload of bales (36) in each trip to the field; (4) increasing round bale density by more than 10%; (5) increasing round baler field efficiency by more than 50%; (6) developing a bale accumulator that can stack and drop six square bales at a time at each drop location in the field; (7) developing a square bale de-stacking machine that can reliably de-stack a 2 wide x 3 high stack of bales into a single line of bales for feeding a grinding line; (8) developing an automated round bale infeed line that can automatically remove net wrap and de-bale round bales for feeding into a grinding line; (9) developing a round bale hauling and unloading system that enables rapid high-volume unloading of round bales (20 bales in less than 10 minutes, including automated unloading onto a grinding line; and (10) developing a field-deployable NIR bale probe that can accurately and rapidly measure moisture, ash, glucan, and xylan content in biomass bales.

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NEXT GENERATION LOGISTICS SYSTEMS FOR DELIVERING OPTIMAL BIOMASS FEEDSTOCKS TO BIOREFINING INDUSTRIES IN THE SOUTHEASTERN U.S.

(WBS#: 1.2.3.107)

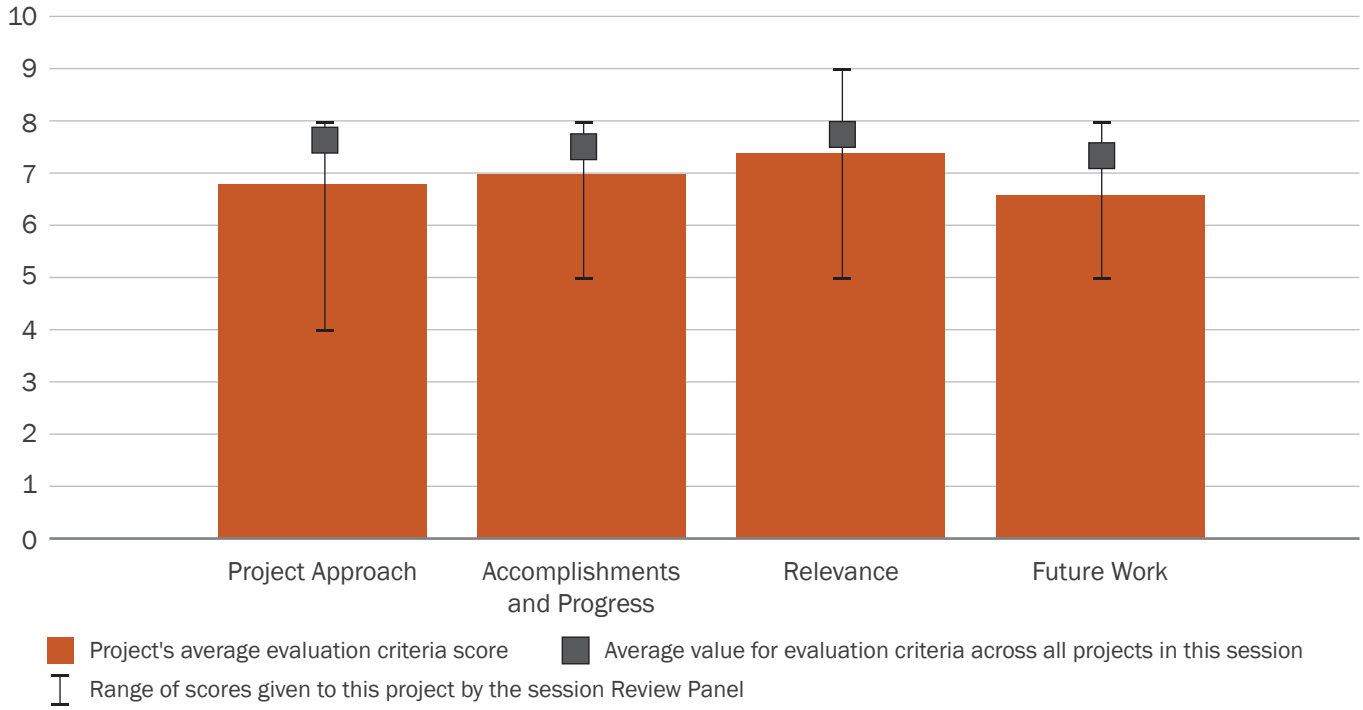
Recipient:	University of Tennessee
Principal Investigator:	Tim Rials
Project Dates:	2/1/2016–1/31/2019
Project Category:	Ongoing
Project Type:	FY 2013—Advanced Biomass Feedstock Logistics Systems II (Logistics II): DE-FOA-0000836
Total DOE Funding:	$4,000,000
Project Dates:	2009-2017

Project Description

The diverse portfolio of biomass sources that is available in the Southeast United States, including a vast supply of pine "residue," creates a valuable strategic position for the region. To realize this opportunity, new systems are required that can utilize biomass with different characteristics to consistently produce a feedstock that meets process specifications. An alternative system for whole tree transport to a state-of-the-art merchandising depot will broaden access to pine biomass from current forest industry operation, minimizing in-woods contamination and lowering overall cost. This biomass source will be available to formulate feedstock to meet process specifications by blending with energy crops, like switchgrass and poplar. Implementing this vision requires new information on the chemical composition and the chemical changes that are induced during the multiple preprocessing steps (e.g., size reduction, moisture removal, and densification). Online sensors based on NIR spectroscopy are under development to monitor important properties of the biomass (i.e., carbon, ash, and moisture content). The newly available bio-

Weighted Project Score: 7.0

Weighting: For ongoing projects, there is equal weighting across all four evaluation criteria: Approach, Relevance, Accomplishments and Progress, and Future Work.



mass quality data will be incorporated into a statistical process control platform, allowing cost saving through process efficiency gains and enabling improved quality and consistency through blending. This capability will ultimately reduce operational risks from supply chain disruptions, while allowing larger-scale biorefineries to be constructed and operated.

Overall Impressions

- This is an important project to assess the feasibility of biomass depots to enable low-cost, high-quality, and abundant feedstock.
- The project is relevant to increase the quality and reduce the cost of the biomass for thermochemical conversion systems.
- The project is on track. However, the different rheological, physical, and chemical properties of the various biomass materials due to blending can be a challenge during pretreatment, enzymatic hydrolysis.
- There is a lot of future work planned but the go/no-go milestones and metrics for success are unclear.
- This project builds on earlier high tonnage projects, and is still early in the funding period. It focuses on the development of a mixed feedstock supply system based on pelleting woody and herbaceous materials together into a consistent product. The project team is large and includes partners with appropriate expertise to meet the project tasks. The plan for high-moisture pelleting leverages other ongoing FSL activities at INL.

  With 33% of the project period past, progress toward the tasks seems to be on schedule. The full tree log trailer has been designed, fabricated, and testing is underway. While the design is apparently successful in increasing the payload, the need for The U.S. Department of Transportation to change highway regulations to allow the use of the trailer raises questions about the industrial viability of that design. A central part of Task 1 is the merchandizing of pine trees at a forest depot.

  From the presentation, it was difficult to identify the progress on that activity. The NIR quality evaluation of Task 2 is well underway, and the NIR models presented achieved high R^2 values. There should be significant synergy with other NIR biomass quality projects funded by BETO, but that was not discussed. Tasks 3 and 4 will be initiated in the near future.

  Certain aspects of the project were addressed during the presentation, and are likely to impact the ultimate success. The project is based on an assumption of producing a mixed feedstock pellet that would be used in thermochemical (pyrolysis) conversion. The preliminary modeling of the conversion as impacted by varying carbon, ash, and moisture demonstrated significant change in the output, but no material was presented as to the acceptable limits for economic viability. Mixing wood and switchgrass to produce the pellets combines processes with biomass harvested year-round and over a short season. The influence of the dynamics of these collection systems did not seem to be included. The project appears to have individual partners conducting the portions that they are responsible for, but it is not clear how the parts will come together to provide a system evaluation.

- Overall, the project has some potential on achieving certain technical barriers. Hopefully, the team will consider addressing key technical barriers quantified to developing advanced supply logistics system and documenting critical performance measures and cost reduction approaches. The project has some opportunities to focus the directions at the interface of feedstock quality and conversion pathway requirement.

PI Response to Reviewer Comments

- The concept of a blended biomass feedstock is not unique to this work. INL has provided detailed analysis of several blended biomass feedstock designed to meet cost and quality targets. We are following this same approach but are actually demonstrating the performance on many of the specific unit operations and the performance of the biomass blends in biorefinery processes. Wood and switchgrass allow for a unique and complimentary supply chain for biomass crops. Wood can be harvested year-round, though weather can dictate access to the woods and regularity of availability. Switchgrass is optimally harvested in the winter, when the plant is dormant, allowing for collection of a biorefinery feedstock that is low in moisture and relatively low in ash, but then requires storage for a year-round supply. Blending the two into a single, consistent feedstock offers synergies in improving operational efficiencies, and reducing risk in the supply chain. Although we are only addressing pine and switchgrass in this project, it is likely that other biomass types could, and would, be incorporated into commercial practice.
- It is true that combining switchgrass and pine feedstocks will have a series of implications on the cost of the final biomass derived hydrocarbon fuel that can be grouped into three categories, as follows:
  - Costs and quality of the raw biomass delivered to the depot
  - Costs and quality of the blended feedstock delivered to the throat of the pyrolysis reactor
  - Cost of the final biomass derived hydrocarbon fuel produced from the blended biomass.

There are tasks in the project that will inform this integrated analysis.

As the Panel noted, the costs of the pine will depend on the effectiveness of the new transportation system. The portion of the whole tree mass allocated to the biorefinery, and the composition and moisture content of this pine fraction will also be important and demonstrated in this work. The composition and costs of switchgrass are reasonably well-established, and the low moisture content will balance the negative impacts of the higher ash content. The costs of creating consistent blends will also be demonstrated in this work. The consistent quality will have to compensate for the increased costs of blending and pelletizing this material. The value of blending these two feedstocks will be evaluated with experimental data generated by the team, and with engineering process models and financial models. The environmental life cycle impacts will also be tracked based on the field and demonstration data, and the process models. These benefits must be greater than the added costs of producing the blended feedstock.

In most cases, the economics will be based on the nth plant. As stated by Dutta et al., the nth plant and its economics assumes that several plants using the same technology have already been built and are operating. This assumes that a successful industry has been established with many operating plants. Because the techno-economic model is a tool used primarily for (1) studying new process technologies or (2) comparing integrated schemes in order to comment on their relative economic impact, it is prudent to ignore artificial inflation of project costs associated with risk financing, longer startups, equipment overdesign, and other costs associated with pioneer plants. According to this report by Dutta et al., these costs "overshadow the real economic impact of advances in conversion science or process engineering research." At the very least, nth-plant economics should help to provide justification and support for early technology adopters and pioneer plants about longer term prospects.

[9] Abhijit Dutta, Asad Sahir, Eric Tan, David Humbird, Lesley J. Snowden-Swan, Pimphan Meyer, Jeff Ross, et al., *Process Design and Economics for the Conversion of Lignocellulosic Biomass to Hydrocarbon Fuels: Thermochemical Research Pathways with* In Situ *and* Ex Situ *Upgrading of Fast Pyrolysis Vapors* (Golden, CO: National Renewable Energy Laboratory, 2015), NREL/TP-5100-62455, https://www.nrel.gov/docs/fy15osti/62455.pdf.

IMPROVED ADVANCED LOGISTICS UTILIZING WOODY AND OTHER FEEDSTOCKS IN THE NORTHEAST AND PACIFIC NORTHWEST

(WBS#: 1.2.3.108)

Recipient:	The Research Foundation of State University of New York (SUNY)/SUNY College of Environmental Science and Forestry
Principal Investigator:	Tim Volk
Project Dates:	4/1/2016–3/31/2019
Project Category:	Ongoing
Project Type:	FY 2013—Advanced Biomass Feedstock Logistics Systems II (Logistics II): DE-FOA-0000836
Total DOE Funding:	$3,000,000

Project Description

The goal of this project is to lower the delivered cost of hybrid poplar and willow woody crops to $84/dry ton by optimizing and demonstrating a supply system while maintaining the quality of the biomass. The project is divided into five task areas: (1) harvest and logistics, (2) transport and storage, (3) preprocessing, (4) feedstock characterization, and (5) logistic and economic modeling. As an iterative process that involves data collection from commercial harvests of woody crops, provision of these data to modeling teams who then suggest improvements for the next field season based on results from model runs. Improvements in the operation of a single pass cut and chip harvesting system and in the optimization of the chip collection, handling, storage, and preprocessing systems will be implemented and tested. Additional objectives include overcoming technical hurdles to develop coordinated and optimized harvesting, transport, storage and delivery logistics so that feedstock of consistent quality and quantity can be delivered year-round. Preprocessing techniques including drying and densification with INL's PDU and hot

Weighted Project Score: 7.7

Weighting: For ongoing projects, there is equal weighting across all four evaluation criteria: Approach, Relevance, Accomplishments and Progress, and Future Work.

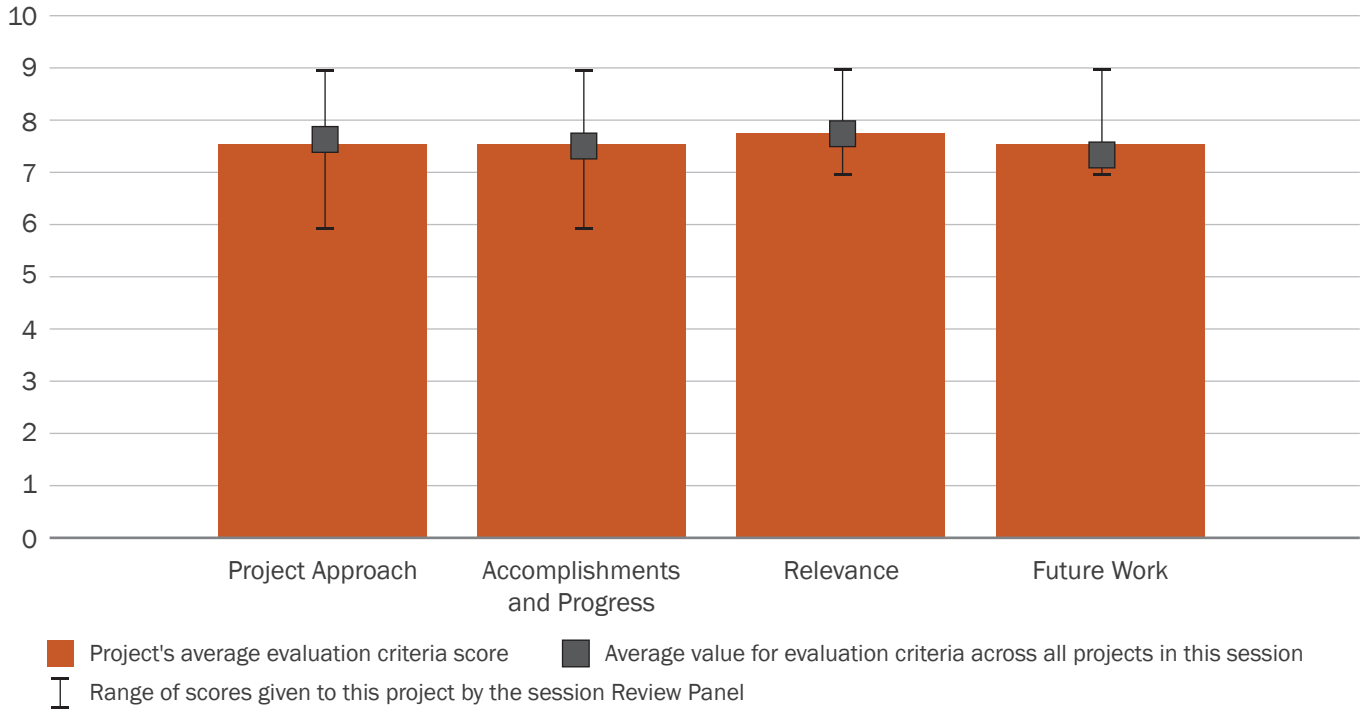


Photo Courtesy of SUNY

water extraction techniques will be tested to reduce variability of feedstock characteristics that are important to end-users. Rapid biomass quality assessment techniques based on NIR technology will be developed so that the quality of the feedstock can be assessed throughout the supply chain.

Overall Impressions

- Overall, this is a straightforward project that leverages other investments (Sun Grant) and commercial activities to reduce the cost of woody biomass.
- The project seems to lack innovation and is in the early stages of implementation.
- NIR data on woody biomass have been done by other agencies such as NIFA coordinated agricultural projects. USDA/DOE integration is recommended.
- This project is well-designed and addresses the entire woody supply chain in a logical and integrated fashion.
- This is a well-organized project that builds on the results of the earlier high tonnage biomass logistics project awarded to the same group. It is directly addressing BETO goals. Appropriate progress has been made relative to the project timeline. No major weaknesses were identified for this project, although there was concern over the size of piles used in evaluating storage systems for the chopped material. Small piles with high surface to volume ratio (as shown in the presentation) likely will not provide the same storage results as industrial sized piles with smaller surface/volume ratios. NIR quality assessment should be coordinated with the work in multiple other BETO projects to maximize the value and accuracy of the quality data.
- Overall, the project has some potential to improve the supply logistics system and assessing the feedstock quality. It would be highly helpful if the project could break down the general barriers into specific technical barriers related to feedstock or end-user needs.

PI Response to Reviewer Comments

- We are working with two of the other BETO-supported harvesting and logistics projects to share ideas, knowledge, and develop NIR models collaboratively that will be as robust as possible. We have also been able to draw on some previous, preliminary work that has been done on willow at the SUNY College of Environmental Science and Forestry, Cornell, and GreenWood Resources as part of previous projects. GreenWood Resources will develop an NIR model to characterize non-commercial sections of hybrid poplar trees grown for solid-wood products. This includes the evaluation and incorporation of knowledge and models developed during the Sun Grant partnership (Project Title: Hybrid Poplars as a Regional Ethanol Feedstock: Its Development, Production and Economics).

  The concerns about piles and NIR assessments are addressed in previous comments.

BIOMASS FEEDSTOCK NATIONAL USER FACILITY

(WBS#: 1.2.3.3)

Project Description

Biomass handling and feedstock preprocessing challenges have resulted in long startup time and low throughput of pioneer-integrated biorefineries. Challenges include the following: (1) an inability to quickly and accurately detect variation in properties of raw biomass delivered to the biorefinery, specifically the moisture and inorganic content, and (2) an inability to reliably process biomass with varied properties into feedstock that consistently meets conversion specifications.

BFNUF advances the BETO goal of growing a bioeconomy by engaging with industry in the scale-up of biomass preprocessing systems and by developing robust biomass preprocessing technologies to overcome variability and feed handling challenges. The project is designed to address these variability and handling challenges with an adaptive control system integrated into BFNUF's PDU, a full-size feedstock preprocessing system. Sensors detect variability in the biomass and intelligent algorithms, incorporating PDU data as the basis for control system development, and adjust PDU equipment to compensate. Preliminary results show that the adaptive control logic improves the operability and throughput of two-stage grinding of high-moisture corn stover bales.

Recipient:	Idaho National Laboratory
Principal Investigator:	Quang Nguyen
Project Dates:	7/3/2008–9/30/2018
Project Category:	Ongoing
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$2,000,000
DOE Funding FY 2015:	$2,130,000
DOE Funding FY 2016:	$1,700,000
DOE Funding FY 2017:	$1,700,000

Weighted Project Score: 7.9

Weighting: For ongoing projects, there is equal weighting across all four evaluation criteria: Approach, Relevance, Accomplishments and Progress, and Future Work.

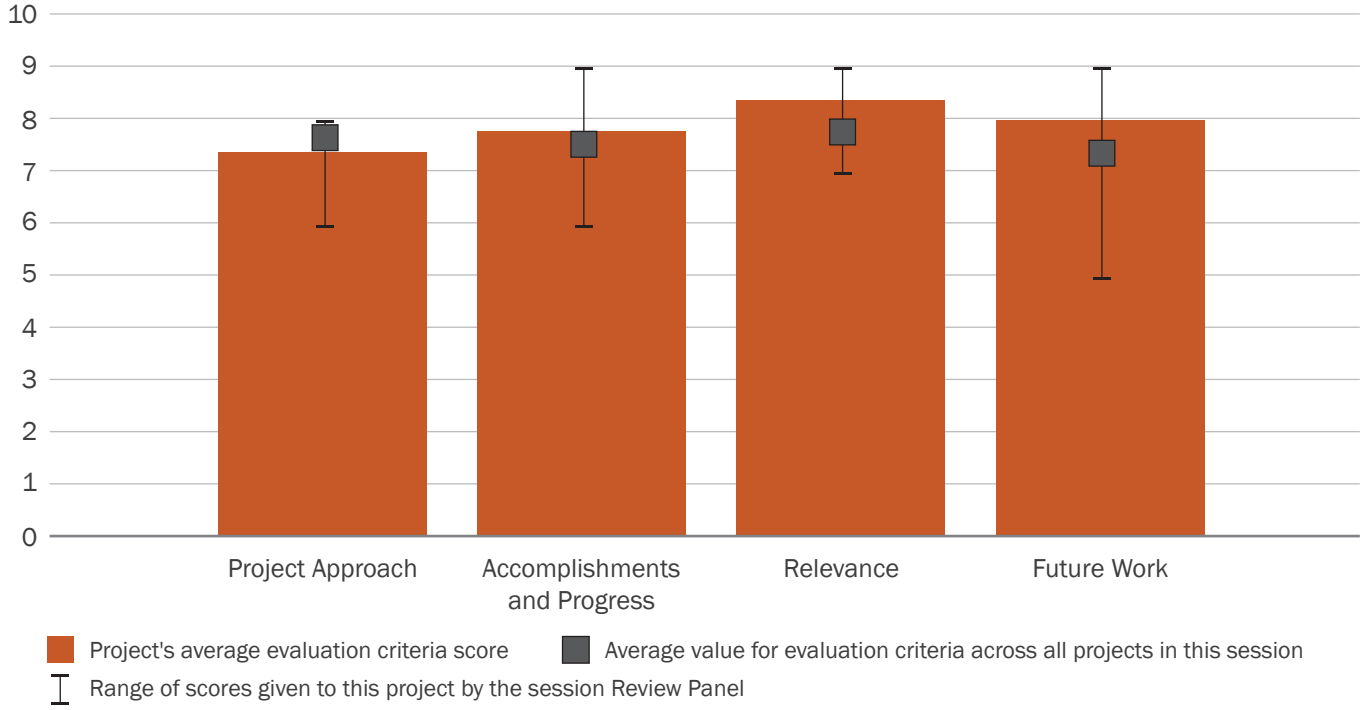


Photo Courtesy of Idaho National Laboratory

Overall Impressions

- BFNUF provides a valuable and unique asset to the FSL program. The ability to examine either individual unit operations in a feedstock supply chain or, ideally, the entire system of processing and conveying unit operations provides a necessary capability for supporting the development of a commercial scale biofuels industry. The development of the adaptive control grinding system clearly demonstrated the ability of the facility and the related personnel to address critical problems. Mention of the 1984 Rand Corporation report[10] on the difficulties faced on startup by facilities handing bulk biomass materials was particularly pertinent, and provides a justification for research into methods to minimize the bulk handling/processing challenges. While BFNUF has demonstrated value, there remain several concerns about its ability to maximize success. Some of these are structural in the organization of and expectations for the unit.

  The unit has been asked to be self-supporting. Funding can come from industrial users who pay 100% of costs for their tests, or from non-proprietary projects, which are charged only 50% of the costs. Most of those reduced rate projects are BETO projects. At the same time, the unit is expected to do R&D projects such as the grinder control system. Since the review team was told that the number of full cost industrial projects has been limited, the managers of the facility should determine if this was due to a lack of demand, competition from original equipment manufacturer test laboratories or limitations such as concern over control of intellectual property rights. There is a fundamental conflict between an expectation that the BFNUF be self-supporting and also conduct research on enhanced operations. The necessary high levels of full-charged industrial project needed to reach the self-supporting goal are very likely to limit the achievement of BETO-focused research projects.

  The unit is advised to concentrate efforts in two areas: (1) fundamental understanding of the limitations of unit operations over a wide range of biomass conditions (e.g., species, moisture ash, etc.), and (2) system performance throughout an entire preprocessing operation set. Enhancing the fundamental knowledge of unit operations as a function of the biomass properties will provide significant value, both to the second effort on overall system performance, and to the need to identify a quality basis for pricing biomass. This, of course, ties into the efforts to develop sensors that can rapidly assess quality parameters.

  This project must be a central part of the FCIC portfolio.

- Overall, the project has established a series of PDUs that could be used for bioenergy industries to minimize feedstock risks and validate or optimize conditions suitable for commercial success. It is anticipated that the project team will identify barriers and develop strategies for increased use of this facility.

[10] Edward W. Merrow, *Linking R&D to Problems Experienced in Solids Processing* (Santa Monica, CA: RAND Corporation, 1984), https://www.rand.org/pubs/papers/P7034.html. This paper is also available in print form.

PI Response to Reviewer Comments

- There are several challenges to reaching BFNUF's goal of becoming self-sustaining, including the following:
  - BETO-sponsored projects take highest priority, and yet do not fully utilize the User Facility capability all the time. Nevertheless, the User Facility must be fully staffed in order to support these projects.
  - The PDU tries to fill in the gap with external contract work, but these small projects do not often fit in the schedule, which lead to inefficient use of resources and limited contract work.
  - The PDU's limited capability and specialized equipment do not allow broadening services. The current cumbersome contractual procedures do not allow quick response to industrial requests for quick acceptance of new work.

We are trying to improve the capability of the PDU by requesting new funding from BETO. We are working toward streamlining contract agreements to better respond to requests from industry. We are partnering with two industrial leaders in biochemical and thermochemical conversion in submitting a proposal to DOE-BETO's and the USDA National Institute of Food and Agriculture's joint Integrated Biorefinery Optimization FOA to develop robust feedstock preprocessing and reactor feeding systems.

US-INDIA CONSORTIUM FOR DEVELOPMENT OF SUSTAINABLE ADVANCED LIGNOCELLULOSIC BIOFUELS SYSTEMS

(WBS#: 2.5.2.7)

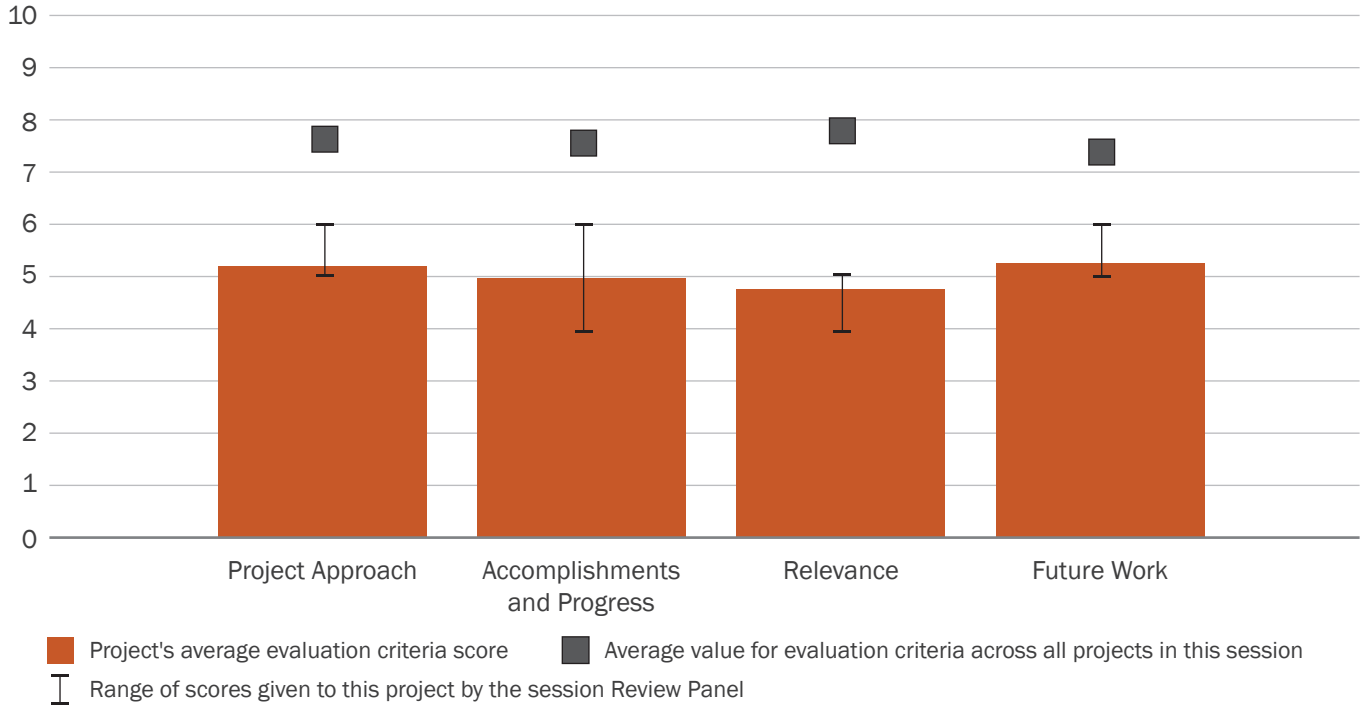
Recipient:	University of Florida
Principal Investigator:	Wilfred Vermerris
Project Dates:	9/18/2012–9/17/2017
Project Category:	Ongoing
Project Type:	Other
Total DOE Funding:	$6,213,857
Project Dates:	2010-2015

Project Description

This project is a collaborative effort between institutions and companies in the United States and India that participate in the U.S.–India Joint Clean Energy Research & Development Center. It emphasizes sustainable feedstock cultivation and supply, biochemical conversion technologies for production of butanol, and analysis of sustainability and supply chain management. The specific objectives of the United States' component of the project are to (1) genetically improve biomass-sorghum feedstocks to generate cultivars and hybrids adapted to flooding or drought, (2) use switchgrass research plots on commercial farms to identify soil and environmental criteria that will ensure commercially successful feedstock production on marginal lands, (3) develop novel microbial biocatalysts for the production of butanol from switchgrass and sorghum biomass, and (4) develop products from biorefinery residues that minimize environmental impact and maximize revenues. Furthermore, a sustainability analysis is being conducted, which includes development of certification protocols and sustainability standards, assessment of energy requirements and emissions, and economic analyses as the basis for successful supply chain management. Successful completion of the project is expected to result in benefits the United States and India by delivering a validated commercial working model for feedstock production and supply, biochemical conversion and affiliated biorefinery technologies as part of an integrated sustainable supply chain.

Weighted Project Score: 5.1

Weighting: For ongoing projects, there is equal weighting across all four evaluation criteria: Approach, Relevance, Accomplishments and Progress, and Future Work.



Overall Impressions

- Overall, this project provides some useful information for feedstock production (both breeding and agronomy), but must be more balanced and integrated to be useful. The conversion and life cycle analysis (LCA) aspects were not as compelling, but likely still useful.
- The value proposition needs to be established to justify the project; it has too many components diluting the efforts thus decreasing the value of the work.
- The project helps in the creation of academic capabilities and the training of the human resource for the deployment of the biorefinery industry.
- It is unclear if there is a use (if any) of generated waste streams. There is an overly optimistic goal of increasing butyrate yields from 45 g/L to 100 g/L by genetic modification. The presenter needed to clearly present project accomplishments and costs associated with byproducts.
- This project has many objectives that seem to have been poorly integrated, and accomplishments to date have been limited. The loss of industrial partners and the University of Florida biorefinery pilot plant have been complicating factors. Some progress was reported in identifying sorghum germplasm for flooding and sugarcane aphid (an addition to the project objectives) resistance. However, it is not clear what the potential for growing biomass in flood prone areas really is.

  Regarding the production of butyrate, a significant improvement in the production rate (45 g/L) was reported, but the path to the goal of 100 g/Lis unclear and perhaps overly optimistic. One of the project objectives is to demonstrate recovery and utilization of biorefinery and waste residues. Progress reported to date was limited to the design of an anaerobic digester for the stillage that would extract methane and possible fertilizer materials. Future work was stated as optimizing the use of biorefinery residues for methane production and soil amendment, but the details provided were insufficient to give confidence that this objective will be achieved.

  This project is a consortium with India, but no information was presented about synergies gained through that consortium. When questioned, the exchange of scientists was mentioned, but the planned exchange of breeding materials was not allowed. While this presentation rightly concentrated on the United States work funded by DOE, I would have expected a functional consortium to have generated enough scientific merit to have warranted mention.

  Many of the comments from the 2015 reviewers still appear to be appropriate for the project in 2017. The progress in the last 2 years has not removed the concerns of those reviewers.
- Overall, the project has made moderate progress on the feedstock development and development of biocatalysts for improved production of butanol and ethanol from sorghum and switchgrass, respectively. The yield potentials and flood tolerance of developed varieties are yet to be determined to attract major bioenergy industries. The progress on the economic and environmental indicators for the specified pathways is still under developed.

PI Response to Reviewer Comments:

- On behalf of the project team, I would like to thank the review team for their time and comments. Responses to the recurring comments include the following:
  - Given the limited amount of time allocated for each project presentation, I chose to give a broad overview of the different activities, rather than a detailed report on a small selection. This meant leaving out many of the details. The statement of project objectives is updated annually, with detailed targets for all activities. Quarterly reports to DOE are used to determine progress towards these targets.

- In terms of the economic benefits, with several million acres of flood-prone land in the United States and over $3 billion in crop losses each year due to flooding, having flooding-tolerant germplasm will reduce crop losses and associated loss in farm income. Crop improvement is a slow process, and it is only now (summer 2017) that we have advanced breeding material available for larger-scale trials that will generate yield data. This includes commercially promising high-biomass sorghum hybrids able to grow on poor soils, and a mapping population segregating for flooding tolerance that will enable us to measure the yield gains resulting from improved flooding tolerance.

  The proposal's original focus on ethanol was changed due to DOE's focus on advanced biofuels, which led to butanol as the fuel of choice. Butanol is toxic to the microbes that produce it. Butyrate, on the other hand, is not, and can therefore be produced at high titer, and reduction of butyrate to butanol is straightforward. The two strategies for industrial production of microbial products are to (1) start with an organism that produces the target molecule but in low product yield or at high cost, or (2) start with an organism that is well-suited for industrial use (e.g., *Escherichia coli* [*E. coli*]) but that does not produce the target molecule. In the latter case, a new pathway needs to be introduced. We have pursued both strategies, maxing out at 45 g/L using the first strategy with Clostridium thermobutyricum, and aiming for 100 g/L with the second strategy in E. coli. This yield target is not unreasonable given industrial production of lactate and succinate. Multiple strategies for improvement of butyrate-producing E. coli are being pursued. Since the presentation the butyrate titer has further increased from 18 to 25 g/L.

  The progress on valorization of lignin-rich residues is, contrary to what is suggested in the review, not restricted to anaerobic digestion. In the presentation, I also showed enhanced plastics with enhanced ultra violet-tolerance. Additional efforts focus on antimicrobial films and use of biorefinery stillage as fertilizer.

- The economic and environmental components of the project are admittedly dependent on data generated by the crop management team and the Biomass Conversion team. This was also pointed out during the presentation. We now have those data in hand, which can be fed into the models that have been generated as part of the project. Some of those models were tested with data available from established production systems in the Midwest, and this is what led to the portfolio management strategy that was presented, and which is intended to mitigate shortages in the regional feedstock supply.

The project plan is updated annually, based on whether milestones set for the preceding year were met. Projects that did not meet their milestones have been discontinued. The current set of activities is more streamlined than at the start of the project, and further streamlining is expected.

In summary, at this point the groundwork has been laid to integrate the data from the different areas and to obtain robust production statistics for the improved crop germplasm, so that at the completion of the project the boundaries of what is and is not feasible will be defined.

WASTE TO WISDOM: UTILIZING FOREST RESIDUES FOR THE PRODUCTION OF BIOENERGY AND BIOBASED PRODUCTS

(WBS#: 3.4.1.4)

Recipient:	Humboldt State University
Principal Investigator:	Han-Sup Han
Project Dates:	9/30/2013–9/30/2016
Project Category:	Ongoing
Project Type:	FY 2012—BRDI (FY12): DE-FOA-0000657
Total DOE Funding:	$5,881,974
Project Dates:	2010-2013

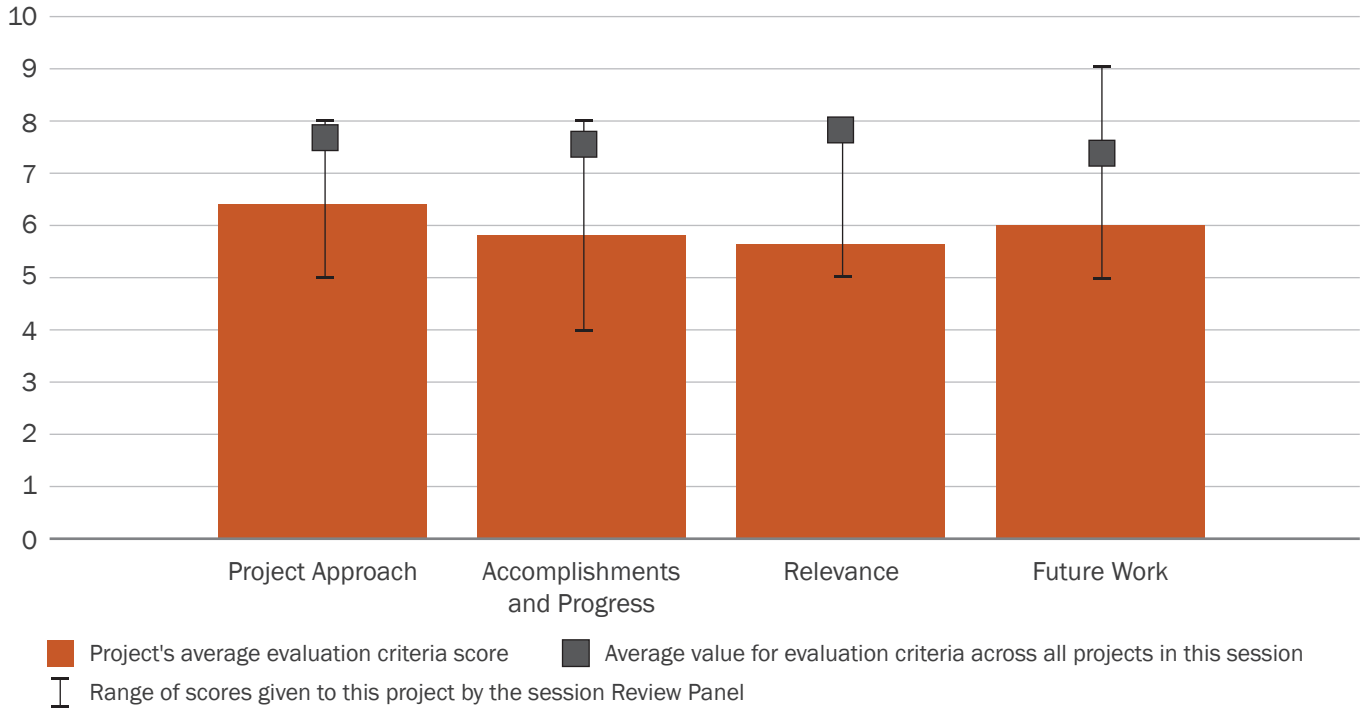
Project Description

Overcoming the barriers to utilizing low-value forest residues that are generated from forest management activities can be accomplished by employing biomass conversion technologies (BCTs). At present, the greatest obstacle to increasing utilization of these materials is the high cost of transportation. BCTs can convert comminuted forest residues into biochar, torrefied pellets, and briquettes; improve their market desirability; increase their value; and increase transportation efficiencies. This project aims to (1) develop system logistics that improve the economics, accessibility, and production of high-quality feedstock; (2) evaluate and scale up standalone BCTs that are operated at or near the forest for their commercialization; and (3) perform economic analyses and LCAs to enhance sustainability of biomass utilization through improved knowledge on socio-economic and environmental benefits.

The Waste to Wisdom project has found that the commercialization of BCTs has the potential to improve the economics of forest management activities, improve forest health, reduce catastrophic wildfire, sequester carbon, and reduce GHG emissions. In addition, the project

Weighted Project Score: 6.0

Weighting: For ongoing projects, there is equal weighting across all four evaluation criteria: Approach, Relevance, Accomplishments and Progress, and Future Work.



Photos Courtesy of Humboldt State University

may create employment in the forest and energy sectors, support economic development in rural areas, and effectively reduce our nation's dependence on fossil fuels by incorporating renewable fuels into current bioenergy and coal-fired energy facilities.

Overall Impressions

- This project does seem to support the forest products industry, but was not clearly relevant to BETO goals. Quality and impact of work over state of the art seemed minimal or not apparent.
- The project had created academic capabilities and provided for the training of students in the bioenergy opportunities.
- Biochar and torrefaction are not new. This project is similar to two Agriculture and Food Research Initiative coordinated agricultural projects funded in Washington. There has not been much output for the length/duration of the project. There is a lack of cost assessments of pilot plant products. Objectives/goals overlap with other projects presented at the BETO Project Peer Review.
- The results of this project are not clear. One main result should be to determine which production pathway (biochar, torrefaction, or densification) is most logistically feasible, cost-effective, and sustainable.
- This project examined alternatives for converting West Coast forest residues into potential forms that could be utilized for biomass energy. The project has attempted to demonstrate biomass upgrading technologies at forest sites, and the project is nearing its completion. Biochar, torrefaction, and briquetting were all demonstrated.

  The project intended to "...meet the price target ($50–$60/dry ton) with low ash contents (<1%)," but unfortunately, inadequate data were presented to compare results to these cost and quality targets. Data presented were generally subjective in nature, and when capacities of developed equipment were described, they were judged as successful when not meeting the target levels. After conducting the three demonstrations, the authors did not identify which of the alternatives would be most viable. While no complete analysis of the cost for delivered biomass in the form of biochar, torrefied, or briquetted material was provided, the costs reported for each machine operation provided in the extra pages seem to indicate that none of the examined systems could approach the BETO goal of $84/demonstration and market transformation. The projections of potential jobs that might be created and the survey of public opinion about bioenergy were irrelevant to the focus of this project.

  Although only a few months remain on this project, future work should concentrate on reporting on the feasibility of industrial scale operation of the examined systems and the likely delivered feedstock cost

for each system. The remaining $1.6 million in the project should be focused on these efforts.

- Overall, the project has successfully addressed the integrated torrefaction and densification of woody biomass at a scale suitable to address technical feasibility of producing high-quality solid fuel. The project will hopefully address the issues related to converting forest residues into high-value solid biofuels along with targeted economic and environmental benefits.

PI Response to Reviewer Comments

- The Waste to Wisdom project management team can appreciate the reviewer's concern with the scope of the project and how it relates to BETO goals. We would like to reiterate that this research project was designed, proposed, and accepted as a Biomass R&D Initiative project and therefore the goals and objectives are different from a normal DOE funding opportunity announcement. However, the goals of this project do align with several goals outlined in the 2016 BETO MYPP as mentioned in our relevance response.
- The management team would like to reassure you that we are following our proposed work scope and that we are on track to meeting all our project obligations. A significant delay in funding at the onset of the project forced a reorganization of the planned schedule. In addition, a switch in a major project partner created additional progress delays. These situations led to a request for a 1-year, no-cost extension. This extra time was necessary for us to complete important tasks and to move the project into the analysis phase. We anticipate finishing all project work tasks by the end of the fourth quarter of 2017.

CLEAN ENERGY MANUFACTURING ANALYSIS CENTER (CEMAC)

(WBS#: 6.3.0.8-10)

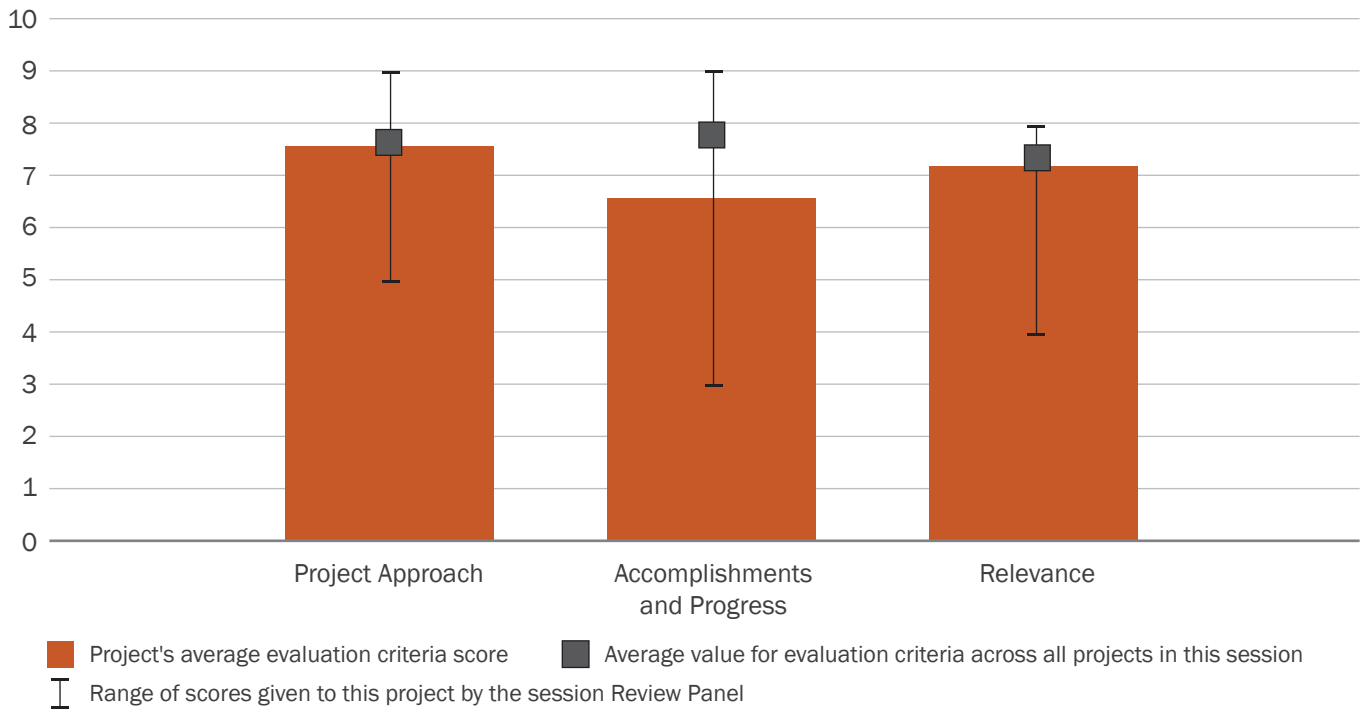
Project Description

CEMAC performs high-impact analysis, benchmarking, and assessment of supply chains and manufacturing for clean energy technologies that can be applied by decision makers to inform R&D, policy, and investment directions. Established in 2015, CEMAC is housed at the National Renewable Energy Laboratory and engages DOE, U.S. federal agencies, national laboratories, universities, and industry to promote economic growth and economic competitiveness. This collaborative project, which includes INL, National Renewable Energy Laboratory, and Oak Ridge National Laboratory, works to evaluate the manufacturing of agricultural equipment that would be necessary to meet the feedstock requirements for a large-scale biofuels industry. This work will outline the transitions needed between the existing conventional supply chains and the advanced logistics and designs necessary to enable the large-scale deployment of biomass. The final product of this study will be a series of presentations and reports that outlines the forward-looking market drivers and barriers, the timelines required to bring equipment to market, and the costs associated with transitioning to these new systems. In addition, the study will work with industrial stakeholders to summarize business decisions regarding where to locate manufacturing facilities (in the United States or abroad) and to provide preliminary estimates on how biomass feedstock expansion could impact the U.S. economy.

Recipient:	National Renewable Energy Laboratory
Principal Investigator:	Maggie Mann, Quang Nguyen, Erin Webb
Project Dates:	10/1/20163/31/2018
Project Category:	New
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$0
DOE Funding FY 2015:	$0
DOE Funding FY 2016:	$50,000
DOE Funding FY 2017:	$350,000

Weighted Project Score: 7.2

Weighting: Approach–25%; Relevance–25%; Accomplishments and Progress–50%.



Overall Impressions

- This work complements the BETO portfolio by supporting the equipment industry needed to facilitate low-cost, high-quality, abundant biomass supply.
- This is a good effort to start planning for the growth of the industry in the long term.
- Valuable information will result from this work. I am glad to see collaboration with the various national laboratories, industry sector, and government agencies. Input of industry is crucial for the success of this project. I recommend that the project team validate existing models related to long-term trajectory.
- This work has value, but I don't think BETO should be leading this effort. It seems like there are many more pressing issues facing a billion-ton bioeconomy.
- This project focuses on the assessment of the market for equipment to support the biofuel industry. It represents the BETO contribution to the larger Clean Manufacturing Initiative of DOE. The result of this project has been the estimation of equipment and labor needs for the corn stover industry.[11] Future plans are to develop machinery needs for the advanced format feedstock system.

  While the CEMAC engagement with original equipment manufacturers through American Society of Agricultural and Biological Engineers conferences is to be congratulated, this project represents a low priority activity for BETO. One of the lessons learned from interviewing equipment manufacturers is that the industry is responsive to the near-term market demands. Surveys of future market demand by a biofuels industry that is having difficulty growing are of little impact. The planned activities require the projection of what logistics systems will be needed in the future, a problematic task at a time when active research is underway to identify those needs. This is a relatively small project that is entirely focused within the DOE-associated national laboratories. These funds could be better used at the laboratories to support the feedstock/conversion interface initiative.
- Overall, the project is focused on streamlining the FSL equipment and their feedstock specifications to meet biorefinery requirements. The project also has a potential to assess the socio-economic benefits of feedstock supply industries to a U.S. bioeconomy. Feedstock supply industries are key contributors to a bioeconomy along with bioconversion facilities (biorefinery).

PI Response to Reviewer Comments

- We thank the reviewers for their very helpful comments and suggestions. As we advance in this project, we will work to incorporate the feedback from the review team. Our overall objective in this CEMAC project is to understand the supply chains required for the agricultural equipment that will support the billion-ton bioeconomy and the potential impact that the growth of this industry can have on U.S. manufacturing and U.S. jobs. This project is looking far into the future to consider what equipment will be needed to enable this growth so that we can inform DOE, the stakeholder community, and the policy and decision makers to support U.S. economic growth. More specifically, we are working to understand how, as this field emerges, the United States can drive the creation of jobs and infrastructure to be a world leader in the manufacturing of agricultural equipment and support the needs of the bioeconomy.

[11] M. Ebadian, S. Sokhansanj, and E. Webb, "Estimating the Required Logistical Resources To Support the Development of a Sustainable Corn Stover Bioeconomy in the USA," *Biofuels, Bioproducts, and Biorefining* 11, no. 1 (2017): 129–149, doi:10.1002/bbb.1736.

To meet this goal, we must first understand what equipment might be required in these future scenarios and how it may vary from the equipment utilized to harvest and process conventional feedstocks in today's supply chain. The ongoing work supported by BETO has shown that conventional equipment will not meet the quality specifications required at the biorefinery gate and that modified equipment will be required to meet the quality and volume requirements. Therefore, this project builds on work led by Oak Ridge National Laboratory to consider these supply chains and from work led by INL to understand what is needed to meet the volumes and quality of feedstock in the future to support the needs of the bioenergy industry.

This project is working to fill an important need in the BETO portfolio by beginning to identify what potential gaps there are in U.S. manufacturing of agricultural equipment and how policymakers and funding agencies can help close those gaps in the near-term to support the growth of an emerging industry. This project seeks to develop and expand the metrics for BETO and biomass stakeholders to consider when investigating the biomass value chain, and provides a start to understanding the broader impact that the development of the bioindustry will have on the overall United States and global economy and how the United States can position itself to be a world leader in this field.

SDSU, SUN GRANT INITIATIVE, REGIONAL BIOMASS FEEDSTOCK DEVELOPMENT PARTNERSHIP

(WBS#: 7.1.2.1)

Recipient:	South Dakota State University
Principal Investigator:	Vance Owens
Project Dates:	7/30/2008–9/30/2016
Project Category:	Sun-setting
Project Type:	Congressional District Program
Total DOE Funding:	$10,492,000

Project Description

The purpose of this program is to utilize a congressionally directed DOE project at South Dakota State University (SDSU) and the North Central Regional Sun Grant's Competitive Grant program to address key issues and research gaps identified via the Sun Grant/DOE Regional Biomass Feedstock Partnership. SDSU agreed to employ the North Central Regional Sun Grant Center to administer a competitive grant program supporting the Regional Biomass Feedstock Partnership utilizing the Sun Grant's authorization as a guide. Research that has been funded is germane to the sustainable production, harvest, transport and delivery of cost-competitive, domestically grown biomass. A total of 18 competitive projects were funded in 11 states. Nine internal projects were awarded as well as six proof of concept projects. These 33 projects have covered a diverse array of topics.

Overall Impressions

- The project advanced collection, harvesting, storage, and transport systems and quantified the benefits of energy farms.
- Overall objectives/technical approach/ accomplishments were not clearly stated. Collaboration with other national laboratories would have been a plus.

Weighted Project Score: 7.0

Weighting: Approach–25%; Relevance–25%; Accomplishments and Progress–50%.

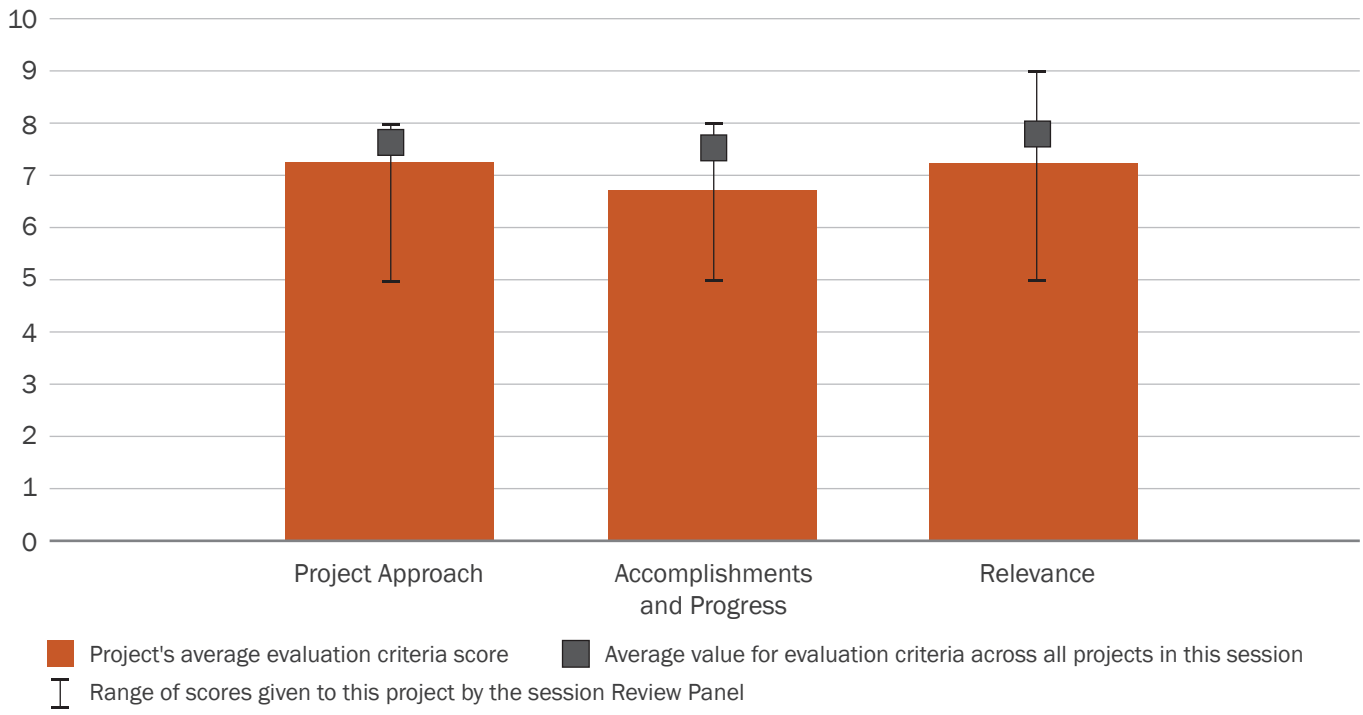


Photo Courtesy of South Dakota State University

- Two activities of this completed project were reported. The Prairie Eco-Farm development examined the potential for a farming enterprise that would focus on grasses as the primary source of income provided value in documenting the income levels that could be achieved. However, the fact that the farm largely returned to row crop production when the project funding ended also demonstrated the limitations of that approach.

  The second project addressed improvement of the corn stover supply chain in support of a biorefinery. This project provided significant value in terms of improving the productivity of the stover collection, storage, and delivery system. It benefited from synergies with the BETO-funded high tonnage logistics systems that overlapped it in time. This project clearly aligned with and contributed to BETO's mission and goals.

- Overall, the project has accomplished some regional success related to biomass development and FSL systems. The technical successes are too diverse and may be further integrated to assess the overall success relevant to bioenergy industries.

PI Response to Reviewer Comments

- This project, through numerous sub-awarded projects across the nation, supported the DOE goal of producing a sustainable, cost-competitive supply of biomass feedstock. It was probably a little unconventional simply because it utilized these congressionally directed funds through the existing Sun Grant Initiative to identify and fund research projects relevant to the sustainable production, harvest, transport, and delivery of cost-competitive, domestically grown biomass.

RESEARCH, EXTENSION, AND EDUCATIONAL PROGRAMS ON BIOBASED ENERGY TECHNOLOGIES AND PRODUCTS

(WBS#: 7.1.2.2)

Recipient:	North-Central Regional Sun Grant Center, South Dakota State University
Principal Investigator:	Vance Owens
Project Dates:	8/1/2005–12/31/2016
Project Category:	Sun-setting
Project Type:	HQ-Directed
Total DOE Funding:	$20,619,986
Project Dates:	2010-2013

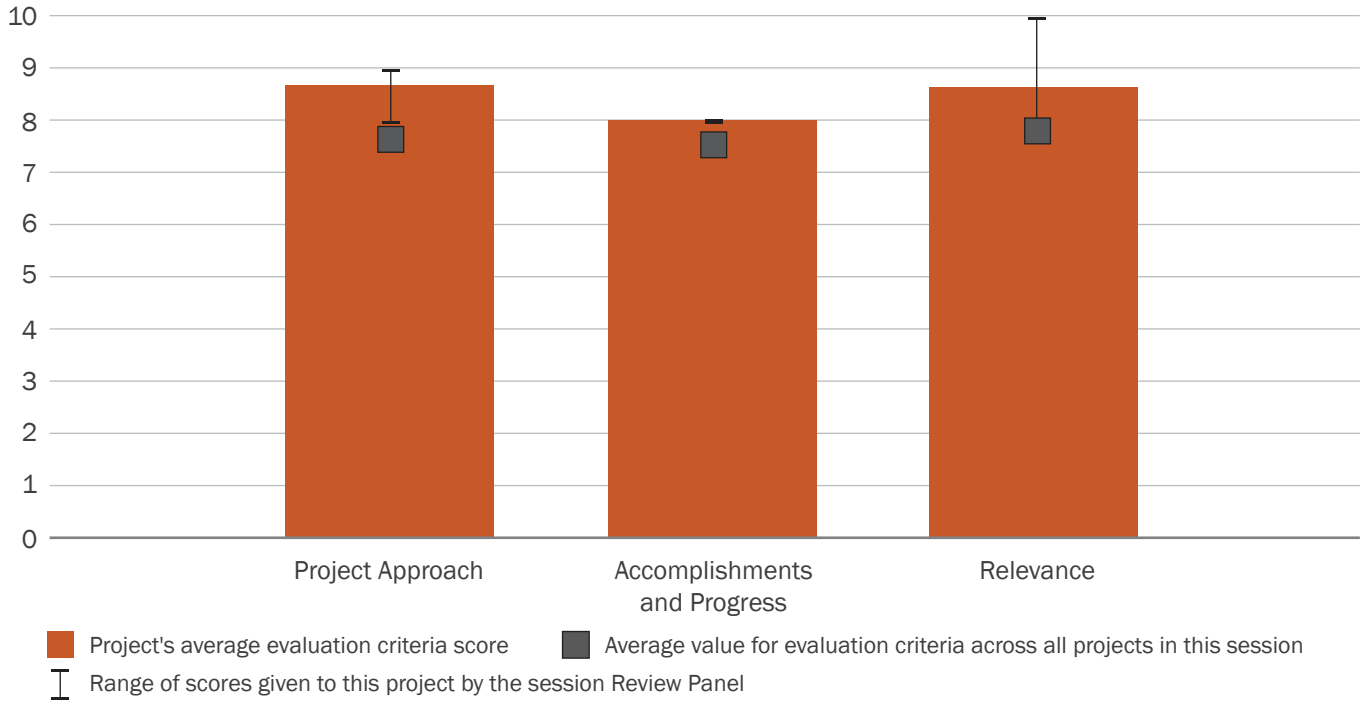
Project Description

The purpose of this program is to help develop more accurate feedstock cost supply information and improved communication with partners in the biomass feedstock supply chain. To accomplish this, replicated field trials were established across regions to determine the impact of residue removal on future grain yield and to develop energy crops within geographical regions. Further, a regional assessment of feedstock resources has been completed to determine feedstock supply curves. Field trials of corn, switchgrass, miscanthus, sorghum, energy cane, Conservation Reserve Program land, poplar, and willow were initiated in 2008, with some sites coming online one or 2 years later and some sites being planted before 2008.

Corn and sorghum final work were reported at the 2013 Peer Review and Conservation Reserve Program and sorghum were reported in the 2015 Peer Review; therefore, they will not be reported in this review. Data collected in this project are highly relevant to industry as biorefineries are sited and to policymakers as they evaluate bioenergy practices. These data have been uploaded to the KDF for use by the public, a key for making informed decisions regarding future bioenergy

Weighted Project Score: 8.3

Weighting: Approach–25%; Relevance–25%; Accomplishments and Progress–50%.



Photos Courtesy of South Dakota State University

projects. Numerous scientific publications (including two special journal issues) and presentations, book chapters, websites, and reports (including a final summary report) have been produced from these efforts. In addition, BioWeb is an important outreach component of this research.

Overall Impressions

- Overall a comprehensive multi-year program to establish the feasibility of energy crops. The woody crop efforts are more mature and commercially relevant to deployment and commercialization of the crops. The herbaceous crops (miscanthus, energy cane, and switchgrass) provide relevant results to continue the development for the deployment and commercialization of the technology. The PI and the scientific collaborators should identify the gaps and propose recommendations for future research.

  The mapping methods and analysis is an excellent reconciliation of available data, experimental results, expert judgment and use of relevant validated models for mature crops.

- The Sun Grant project significantly strengthens the role of energy biomass (herbaceous and woody biomass) potential in the U.S. bioenergy portfolio. The project has provided a fundamental underpinning of BETO's analyses of the potential biofuels industry. Significant advances in improving herbaceous and woody biomass production resulted.

  This project was necessary, and the data provided are extremely useful. Those data are limited however. The range of study sites was limited, and the study protocols did not include important information. Just as the Feedstock-Conversion Interface Consortium has been recognized as an area needed to be addressed, the interface between the energy crop and the logistics system that will harvest and deliver it also must be well-understood. Nitrogen and carbon balances for energy crops require further investigation.

  The PIs of this project should be charged with conducting an assessment of the knowledge gaps that remain for their various feedstock crops. While a second round of study is not anticipated at this time, one of the needed outputs is that identification of research that remains to be done.

- Overall, the project has aimed to develop new energy crops, both herbaceous and woody crops, across the nation using regional sun grant partnerships. The project has developed a portfolio of biomass crops suitable for each region and disseminated the project outcomes through education and extension media.

The project also has a multidisciplinary team of scientists, researchers, educators, and policy analysts to focus on the critical issue of national energy security and local or regional economic development.

PI Response to Reviewer Comments

- We also feel that this has been an important project both in length and breadth. The opportunity to maintain field trials, particularly of perennial species, for up to 7 years is highly infrequent. As always, there are always questions that remain and further research that is needed, not only on the species evaluated in the Regional Feedstock Partnership, but also on other species that were not studied. Some of these research gaps (e.g., lack of data for some species on the periphery of where they would be recommended) were identified through the in-person meetings between modelers and field trial PIs. In addition, some of this was addressed in the summary report that was developed in 2016. Part of the final technical report, currently being written, addresses some aspects of "where do go from here" as well.