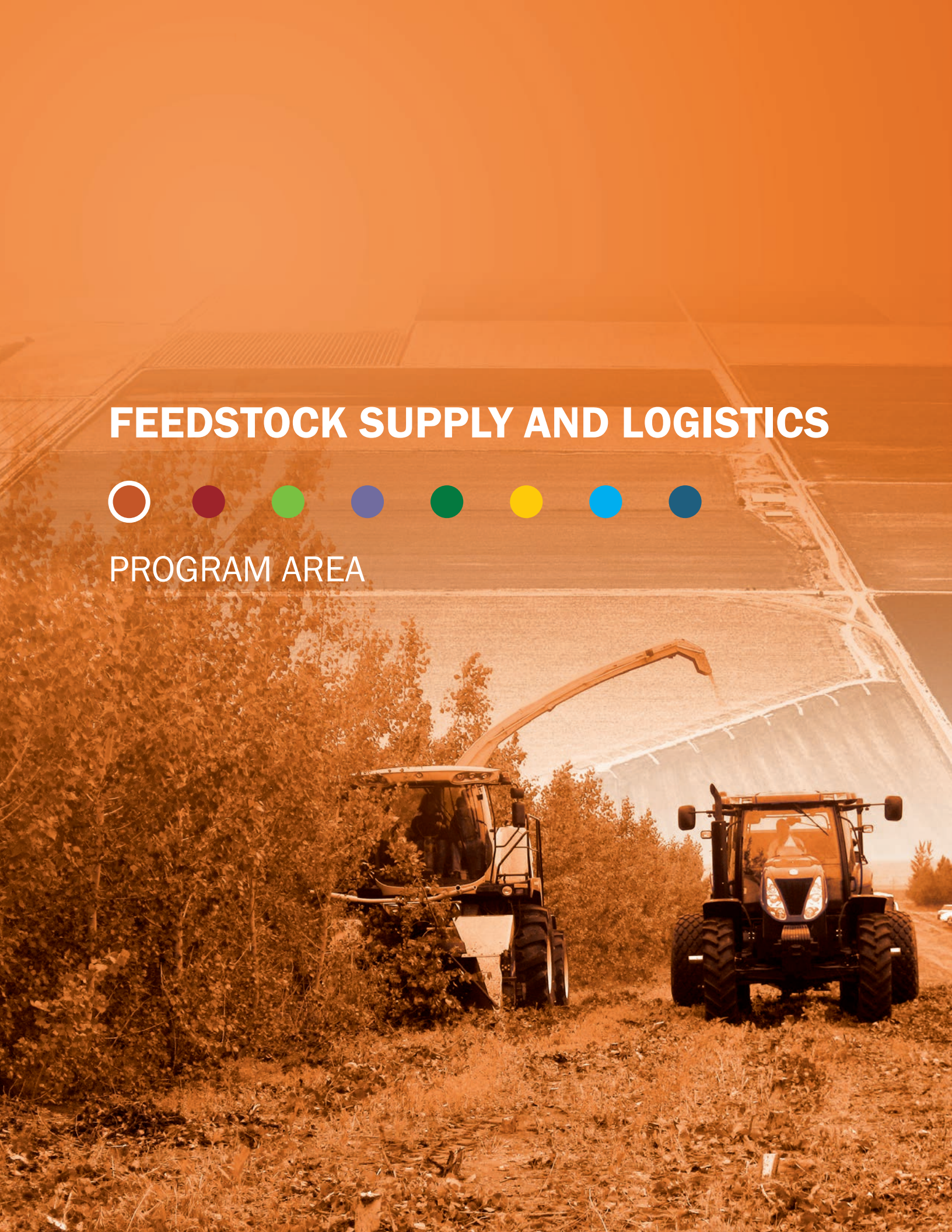
FEEDSTOCK SUPPLY AND LOGISTICS

PROGRAM AREA



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INTRODUCTION

The Feedstock Supply and Logistics (FSL) Program is one of 14 related program areas that were reviewed during the 2019 Bioenergy Technologies Office (BETO) Project Peer Review, which took place on March 4–7, 2019, at the Hilton Denver City Center in Denver, Colorado. A total of 12 projects were reviewed in the FSL session by five external experts from industry, academia, and other government agencies.

This review addressed a total U.S. Department of Energy (DOE) investment value of approximately $40,004,062 (Fiscal Year [FY] 2016–FY 2019 obligations), which represents approximately 4.7% of the BETO portfolio reviewed during the 2019 Project Peer Review. During the Project Peer Review meeting, the principal investigator (PI) for each project was given 20 to 30 minutes (depending primarily on the funding level) to deliver a presentation and respond to questions from the review panel.

Projects were evaluated and scored for their project approach, technical progress and accomplishments, relevance to BETO goals, and future plans. This section of the report contains the results of the Project Peer Review, including full scoring information for each project, summary comments from each reviewer, and any public response provided by the PI. Overview information on the FSL Program, full scoring results and analysis, the Review Panel Summary Report, and the Technology Area Programmatic Response are also included in this section.

BETO designated Dr. Mark Elless as the FSL review lead, with contractor support from Mr. Andrew Kobusch (Allegheny Science & Technology). In this capacity, Dr. Elless was responsible for all aspects of review planning and implementation.

FEEDSTOCK SUPPLY AND LOGISTICS OVERVIEW

FSL research and development (R&D) focuses on technologies and processes that transform renewable carbon sources to biorefinery conversion-ready feedstocks. Terrestrial lignocellulosic biomass (i.e., plants and plant-based materials not used for food or feed) is an abundant, renewable, and sustainable resource for producing biofuels, bioproducts, and biopower. Biomass and other renewable carbon sources or reusable carbon sources commonly used for bioenergy applications include agricultural residues (e.g., corn stover), forestry residues (e.g., logging residues and forest thinning), dedicated energy crops (e.g., switchgrass, miscanthus, energy cane, sweet sorghum, high-biomass sorghum, hybrid poplars, and shrub willows), and waste streams and reusable carbon sources (e.g., the nonrecyclable organic portion of municipal solid waste [MSW], biosolids, sludges, waste food, plastics, carbon dioxide, and manure slurries).

FEEDSTOCK SUPPLY AND LOGISTICS SUPPORT OF OFFICE STRATEGIC GOALS

The strategic goal of the FSL Program is to reliably and efficiently deliver conversion-ready feedstock intermediates to meet BETO's 2022 and 2030 goals of $3/gallons gasoline equivalent (GGE) and $2.5/GGE, respectively. The focus will be on agricultural and forestry residues and energy crops in the near term and economically advantaged feedstocks (such as sorted MSW, biosolids, and industrial waste streams) in the midterm (5 to 12 years).

FEEDSTOCK SUPPLY AND LOGISTICS SUPPORT OF OFFICE PERFORMANCE GOALS

The FSL performance goals outlined in BETO's Multi-Year Plan (MYP) are to (1) identify the key feedstock quality and variability factors for corn stover and pine residues to meet a modeled operational reliability of 80% for advanced feedstock supply-logistics-conversion systems at a modeled delivery cost of $86/dry ton and (2) to deliver corn stover and pine residues with the necessary specifications for 2022 verification in support of a minimum fuel selling price of $3/GGE. In addition, by 2029, to identify the key feedstock quality and variability factors for conversion-ready feedstocks to meet a modeled delivered cost of $73/dry ton.

FEEDSTOCK SUPPLY AND LOGISTICS APPROACH FOR OVERCOMING CHALLENGES

The key barriers addressed by the FSL Program are the quality, cost, and quantity of available renewable carbon sources that can be sustainably supplied and reliably converted into high-quality biofuels, bioproducts, and biopower. To meet requirements of conversion facilities, FSL R&D will need to improve feedstock quality from harvest and collection through delivery while meeting conversion performance and cost goals. The following critical areas will be emphasized within the FSL Program through early-stage R&D:

- Feedstock availability and cost
- Production
- Feedstock genetics and variety improvement
- Sustainable harvesting
- Feedstock quality
- Biomass storage systems
- Biomass physical state alteration
- Material handling and transportation
- Feedstock supply system integration and infrastructure
- Operational reliability.

The FSL Program overcomes these barriers by developing science-based strategies and technologies and defining requirements and specifications to reduce costs, improve quality, and increase the quantity of sustainable, renewable, and reusable carbon-based feedstocks. FSL activities include biomass production (in collaboration with the U.S. Department of Agriculture [USDA]), supply chain analysis, feedstock logistics R&D (including harvesting or collecting, storage, transportation, and preprocessing), and research into conversion-ready intermediates. FSL R&D focuses on improving the efficiency of feedstock logistics operations, developing a fundamental understanding of the interactions between feedstock properties and conversion performance, and identifying the key feedstock quality and performance factors affecting biorefineries. FSL collaborates with the Conversion Research and Development and Advanced Development and Optimization programs for testing and verification of feedstocks and the relevant conversion pathways at the engineering scale. FSL also works with the Analysis and Sustainability (A&S) Program to assess progress and identify and analyze sustainable practices. The FSL Program also works closely with the USDA and other federal agencies through the Biomass Research and Development Board.

This R&D work is performed by DOE national laboratories, universities, and industry partnerships, in addition to the Feedstock-Conversion Interface Consortium (FCIC). The FCIC project portfolio was also reviewed during the Project Peer Review. Please refer to the "Feedstock-Conversion Interface Consortium" section in this document for more information.

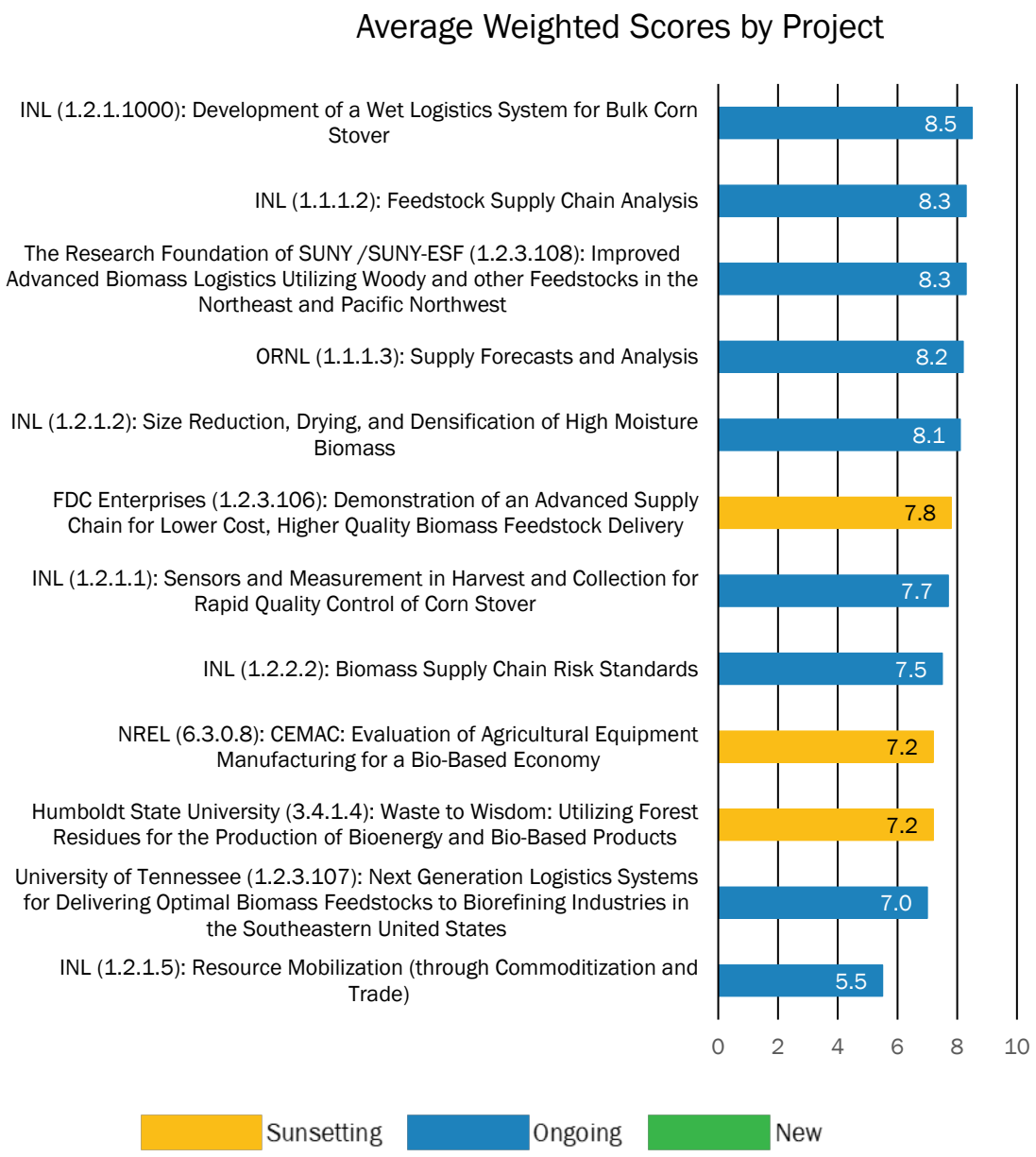
FEEDSTOCK SUPPLY AND LOGISTICS REVIEW PANEL

The following external experts served as reviewers for the FSL Program during the 2019 Project Peer Review.

Name	Affiliation
Glenn Farris*	AGCO Corporation
Brandon Emme	ICM, Inc.
Dana Mitchell	USDA Forest Service Southern Research Station
Ray Miller	Michigan State University
Lynn Wright	WrightLink Consulting

* Lead reviewer

TECHNOLOGY AREA SCORE RESULTS



FEEDSTOCK SUPPLY AND LOGISTICS REVIEW PANEL SUMMARY REPORT

Prepared by the Feedstock Supply and Logistics Review Panel

BETO recognizes that the availability of a sustainable, consistent, economic, and dependable supply of high-quality feedstock is critical to a successful U.S. bioenergy industry. The FSL Program is central to the success of this mission.

The FSL Program projects reviewed encompass forest resources (short-rotation woody crops [SRWC] and forest residues), agricultural residues (corn stover), and dedicated energy crops. FSL projects address a range of topics, including sustainable economic feedstock production, feedstock resource assessments, supply logistics, supply scenarios, supply chain risks, and feedstock quality.

IMPACT

BETO's FSL project portfolio is particularly impactful for industry, and many of the projects will advance the state of technology (SOT) in the handling and logistics area. The government's investments here are particularly appropriate because they address industry problems that in many ways industry cannot address. The national laboratories on their own and sometimes with the involvement of university and industry partners have capabilities that companies alone do not have. This is currently seen in the cellulosic ethanol segment seeking to use agricultural waste, such as corn stover. Early industry projects seeking to convert corn stover into cellulosic biofuels are experiencing problems because of the variability of the material and its effects on downstream processes. This is particularly true when trying to control the moisture and ash content of corn stover.

Two FSL projects have significant direct and indirect consequences for the industry. Both are based on the handling of wet corn stover: Size Reduction, Drying, and Densification of High-Moisture Biomass and Development of a Wet Logistics System for Bulk Corn Stover. When used as a feedstock, large amounts of corn stover must be stored for long periods of time before use. During this time, it can experience significant degradation if wet, and managing moisture during baling operations is both challenging and expensive. Baling wet material, defined as greater than 20% moisture content, is sometimes required because of incoming weather events or farming activities required postharvest of corn grain.

The direct benefits are as follows: Being able to handle wet material and produce high-quality, economic feedstock for the conversion platform solves both the moisture and ash problem (microbial degradation) in the case of a wet logistics management system. For a densification system, intense drying of the material and production of fines in the pellets are the two most significant problems addressed by the project. Less intense drying will decrease the cost of densification, and the reduction of fines will increase efficiency in downstream operations.

Indirectly, the cost of baling material will reduce the cost of the baling operation by at least 10% in a typical three-pass baling system. Further, it would enable the use of the single-pass system, which would reduce baling operation costs by as much as 35%. This system has always been unable to address the storage problems of baling wet material because most baling occurring at or near the time of grain harvest involves wet corn stover. The single-pass system has the added benefit of limiting the ash of collected corn stover to the intrinsic ash of the material because the material is not subject to dirt picked up by being in contact with the ground or picked up by being subjected to dirt blown on it by wind.

The drying and densification and the wet logistics projects are not the only projects in the FSL portfolio that will prove impactful to the SOT as it exists today. Other high-impact projects include those that address in-forest processing systems, advanced logistics supply systems, rapid quality control, and the development of

biomass risk standards. BETO's portfolio is robust, and the review panel encourages BETO to continue existing work as well as fund new work replacing sunsetting projects with new funding opportunities when appropriate.

INNOVATION

The BETO portfolio has several other innovative projects as well. One advanced the SOT for processing forest residues in the forest where they are created and most often left. The technology solutions reduce the moving and handling of the waste, improve forest health, and reduce greenhouse gas (GHG) emissions from the rotting of the residues. The project produced three products that are currently sold in the marketplace, which has the potential to be profitable, depending on local conditions.

Another innovation under development is the next-generation logistics systems in the form of a feedstock collection and processing depot using both woody and herbaceous materials. This concept can become a focal point to produce high-quality economic feedstocks that can then be delivered to any number of fuel, chemical, or power production facilities surrounding the depot. When combined with the wet logistics and wet densification technologies, this concept could be groundbreaking and move the industry toward the commodification of biomass feedstocks.

Sensors for rapid quality control and the development of biomass supply chain risk standards are two more innovative projects. One of the most interesting features of BETO's FSL project portfolio is that many projects use existing technologies in new and innovative ways, and in doing so they pave the way for realization toward the use of the vast biomass resources identified in the *2016 Billion-Ton Report: Towards Commercialization*.

SYNERGIES

One strong point of the FSL Program is the many synergies among the projects. The national laboratory project on Feedstock Supply Chain Analysis includes an analysis of all FSL projects, primarily to support BETO program planning and project tracking needs. This greatly facilitates synergies among FSL projects. In addition, the project incorporates industry data, Supply Scenario Analysis, and other BETO national laboratory projects that include techno-economic analysis (TEA) and life cycle assessment (LCA). The tracking component of the analysis project allows BETO to see if the research projects are meeting their goals in support of BETO's MYP. This project extends well beyond analyzing the cost of feedstock.

Beyond cost, the project's approach integrates the availability of the resources based on supply scenario analysis, improvements in logistics, advancements in technology, and environmental performance. Costs and interdependencies, previously unaccounted for or unidentified, are captured through new and innovative methods and computational abilities to model supply systems. This project naturally creates synergies among FSL projects when it identifies interdependencies and provides a platform for the PIs of any FSL project to locate not only information that can be helpful when problem solving but also encourages communication between the FSL PIs. Such communication is especially encouraged when interdependencies and technical advancements are identified in one area but will benefit another.

To say the final results of the comprehensive data assembly and analysis of feedstock supply chains will become an invaluable industry resource is a severe understatement. It is also valuable for identifying new project funding needs and opportunities to advance BETO's MYP. Although this panel is not familiar with all BETO program areas, this project should serve as a model and be repeated in the other programs where appropriate.

FOCUS

The FSL project portfolio is squarely focused on many issues that will benefit the SOT as it exists today, help existing projects, and spur investment and growth in the advanced bioeconomy. Addressing biomass variability, quality control, borrowing costs, supply risks, and advanced logistics will encourage investment in and the development of new projects in the bioeconomy and help BETO meet its goals according to the MYP.

The FSL review panel has some suggestions, however, for adding and refocusing some project efforts that would strengthen the projects and the review process.

As long as the baling of corn stover, wheat straw, and other feedstocks will be used to supply feedstock to conversion projects, one area that must be addressed is the disposal of baling twine (in the case of large square bales) or bale wrap (in the case of round bales). The disposal of this material is often overlooked, and it will become an imminent problem unless it is addressed. For example, a project that uses 350,000 tons of material per year that is baled and delivered as large square bales will yield between 15,000 and 18,000 miles of baling twine on an annual basis. There are two issues with this: (1) currently, most twine is polypropylene, which is not a bio-based product, therefore affecting issues around sustainability; and (2) the twine needs to be brightly colored to make it easy to see in the field.

When baling corn stover using a large square baler, it is inevitable that the twine will break during the baling operation and be left on the farmer's field. This could cause significant problems for the farmer in succeeding field tasks, such as tilling or planting. If left in the field, the twine could wrap around equipment and cause significant maintenance and operating issues. For the baling team to see and collect the twine, it needs to be brightly colored. Thus, there is a need for a new project to develop a sustainable bio-based twine with the same characteristics as those in the polypropylene.

In addition, the project portfolio would benefit from an impact assessment on the overall effect that the successful completion of the project portfolio technologies will have on the marketplace. For example, ample analysis suggests which price targets advanced biofuels must meet for a gallon of gasoline equivalent to encourage industry development of projects. All the projects have a financial goal—e.g., reducing the gallons of gasoline equivalent by X amount or reducing the borrowing costs of a project by decreasing the credit risk and achieving an investment grade credit. There seems to be little thought (by individual research projects), however, around how many commercial startups would likely occur, when and if the research or demonstration project goals are met, or what other conditions must be met to encourage the development of industry projects. More effort needs to be spent studying the business case for the project products and technologies produced by BETO's FSL work. This would help BETO direct funding toward the most impactful projects.

In addition, many projects would benefit greatly by including field trials involving industry. One sunsetting project (Demonstration of an Advanced Supply Chain for Lower Cost, Higher Quality Feedstock Delivery) showed both the benefits of this approach and the difficulties. Nevertheless, expanded efforts of this nature would give some real-world experience for the products or technologies developed in the FSL portfolio. Field trials would greatly improve the adoption of the FSL work by industry and increase the return profile for BETO's investment. This would give industry a chance to see the work of the national laboratories and universities as well as establish relationships that could prove valuable to both parties in the future. These relationships could also provide new investment opportunities as industry assesses what it needs to address technological challenges.

TECHNOLOGY DEVELOPMENT PIPELINE

Most recent BETO FSL portfolio projects have focused on corn stover and SRWCs, such as willow. The review panel believes that it might be time to expand logistics R&D to other feedstocks that were previously the focus primarily of biomass yield improvement. This is not to say that other feedstocks are not part of any of the studies or projects or that the existing projects would not have any place with other technologies and feedstocks; however, it might be time to start devoting resources to other feedstocks or to the impact that existing projects will have on other feedstocks. The bioeconomy's success will be realized only with a diverse set of feedstock choices, including but not limited to crops such as miscanthus, switchgrass, energy cane, and all forest resources. Even though high-biomass-yield productivity has been demonstrated in the dedicated crops by past BETO and USDA research, and they are included in national feedstock supply scenarios, supply logistics impediments exist to their availability at competitive costs.

One project that should be revisited for additional verification work is the readiness of agricultural equipment original equipment manufacturers (OEMs) to support an aggressively growing advanced bioeconomy. The required amounts of equipment needed are in-line with reports and studies of which the review panel is aware; however, this review panel questions the conclusion that OEMs are ready to produce the required tractors and implements if an aggressive project development growth curve develops. For example, currently the annual market for high-horsepower tractors such as those used in baling operations is approximately 25,000 units. The project estimates that the units needed to pull implements in the short term is slightly less than 50,000 units and in the long term is approximately 55,000 units. If conversion project development takes place throughout several decades, then the ramp-up for OEMs could be managed and planned. Should OEMs need to deliver in a shorter time frame of 10–15 years, this panel is not sure that is possible. More work with OEMs based on a sensitivity analysis with various growth curves would reveal much-needed information about their ability to meet the necessary demand.

For BETO to orient their investments to technologies that would most benefit the developing bioeconomy, the panel believes that BETO would benefit from carrying out a standard business case analysis of the effects on the industry upon the successful completion of a project. This could also become part of the application process when a respondent submits a project for funding under a funding opportunity announcement. This would help separate projects based on business merit and help understand what would or would not be attractive to industry, thereby increasing the chances for rapid adoption by industry. This practice would also reveal whether BETO's investments are occurring at the optimal stage of technology development.

RECOMMENDATIONS

Although it might not be appropriate for all projects, more of a business planning approach to projects should become part of the process. Prior to making any investment, industry frequently if not always requires a business plan and analysis. Analyses on the strengths, weaknesses, opportunities, and threats (SWOT) are performed to indicate how the investment will fit into an existing business and what risks are present versus the benefits to the investment. The panel understands that BETO looks at these types of issues within a general and broad framework, but the panel believes that there would be great benefit to delving into detail in this area. The business plan might gauge the effects of the project and answer such questions as: How and why will the SOT be advanced with a successful project? How many projects will be built and/or how will this project improve existing projects? What will this mean for employment within the industry? This would help BETO create priority for projects and could reveal new opportunities for investment and improvement of existing programs.

The review panel believes that it would be extremely beneficial for each project partner to share with BETO, at a minimum, a report on findings that did not go well or according to plan and how those issues were resolved. This would be most beneficial if shared widely within all BETO program areas. Frequently, projects experience similar problems, and knowing how others solved a problem might save significant time and effort. This would also be useful information to share with industry.

It has come to the attention of the review panel that the national laboratories have within their structure marketing departments. Thus, the final recommendation is that BETO include a budget for marketing as a regular line item. It is not the recommendation that BETO or DOE form a marketing department but that funds be available for specific marketing duties and plans within the laboratories to promote the projects many of them are working on and that BETO is already funding. This would have several positive effects, not the least of which would be increasing the profile with industry of not only the work currently being performed at the national laboratories but also the national laboratory capabilities. This could lead to more future work and/or investment opportunities for BETO.

FEEDSTOCK SUPPLY AND LOGISTICS PROGRAMMATIC RESPONSE

INTRODUCTION/OVERVIEW

The FSL team appreciates the Peer Review Panel statements affirming that FSL funding has enabled research productivity, innovative approaches, and significant advances along the SOT as well as excellent synergies among projects, with no notable gaps. FSL further acknowledges the recommendations that:

- Performing a SWOT analysis would be a potentially useful method for prioritizing projects and revealing new opportunities.
- Reporting on issues that did not go according to plan, and how these issues were resolved, to both the rest of BETO and possibly industry would allow everyone to learn from the "negative" results.
- BETO should use the marketing structures within the national laboratory complex to more effectively communicate the work that BETO funds within both the bioenergy community and the public at large.

Recommendation 1: Business Plan—Incorporate a business plan/SWOT into each project.

BETO recognizes the importance of a sound plan for directing future research that accounts for opportunities and risks. Currently, BETO project planning incorporates an evaluation of the risks associated with each project and the strengths that each project lends toward completing BETO's stated goals and advancing the current SOT in the industry. At this point, project management does not focus on identifying opportunity space. BETO will strongly consider adding an opportunity analysis to the project planning stage.

Recommendation 2: Lessons Learned—Write/share lessons learned and how issues were resolved.

BETO fully agrees with the importance of open dialogue, along with the collection and communication of lessons learned, such that all results can be used. Currently, it is common practice to include a section on lessons learned in each quarterly report sent from project performers to BETO that includes a description of at least one challenge faced by a project and the path for resolving the challenge. BETO will consider a path for aggregating and disseminating this information while remaining sensitive to the protection of proprietary data and information that could be contained within the described challenge and solution.

Recommendation 3: Marketing—Enhance focus on marketing. FSL program should set aside specific funding for marketing to be provided to the national laboratories for execution.

BETO currently works to make its impacts known through conferences, the DOE Office of Energy Efficiency and Renewable Energy website, and other platforms such as social media. We appreciate the review panel's suggestion to extend our outreach and marketing efforts through our national laboratory partners, and we acknowledge a great opportunity to take advantage of BETO's BioComms effort—a communications partnership of nine BETO-funded national laboratories. BETO will work with the laboratories to improve overall outreach and continue to increase the profile of the bioenergy industry writ large. This could be accomplished through ongoing efforts at the laboratories to publicize attendance more widely at conferences, by encouraging national laboratory researcher participation in professional society leadership roles, in addition to better advertising the capabilities of the various national laboratory process demonstration units such that partnerships with industry can be enhanced.

FEEDSTOCK SUPPLY CHAIN ANALYSIS

Idaho National Laboratory

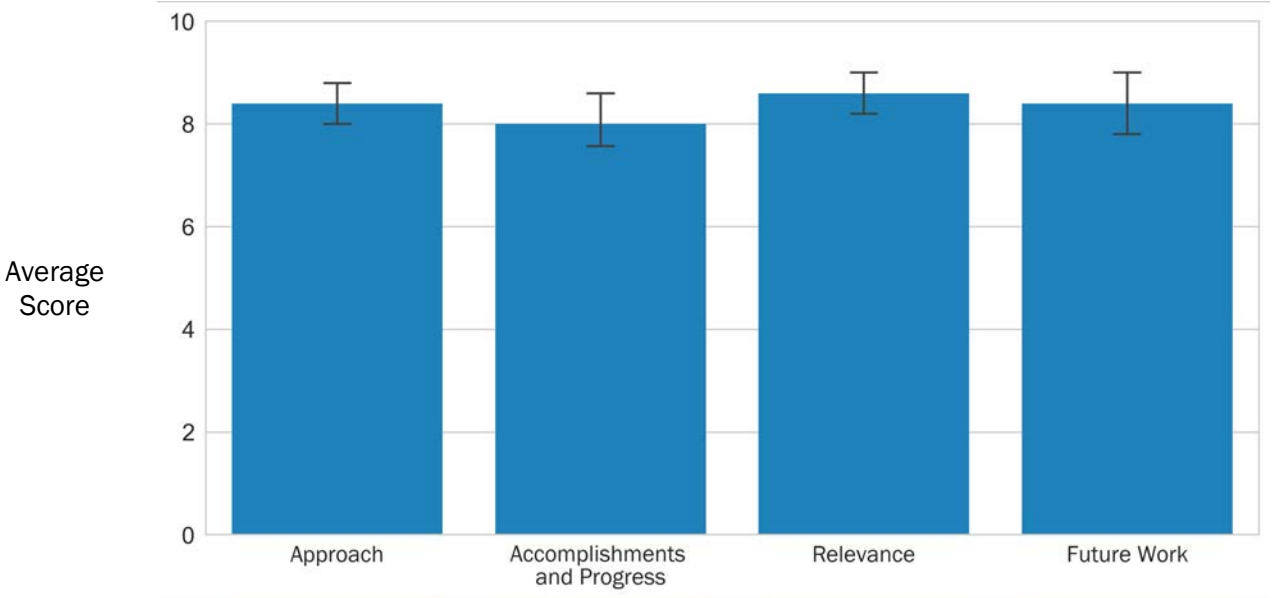
PROJECT DESCRIPTION

WBS:	1.1.1.2
CID:	NL0015591
Principal Investigator:	Dr. David Thompson
Period of Performance:	10/1/2014–9/30/2020
Total DOE Funding:	$3,779,968
DOE Funding FY16:	$765,000
DOE Funding FY17:	$900,000
DOE Funding FY18:	$1,114,968
DOE Funding FY19:	$1,000,000
Project Status:	Ongoing

The billion tons of biomass potentially available for bioenergy comprises widely distributed, low bulk density, and widely spatially and temporally variable biomass types, moisture levels, and compositions. This creates a unique challenge to the development of reliable, cost-effective biorefineries to provide low-cost, high-volume biofuels that can compete with petroleum-based fuels. Today's pioneer biorefinery industry lacks a consistent and reliable biomass supply, and thus it relies on vertical integration of its feedstock supply to minimize supply risk using conventional feedstock supply systems that were developed for industries that are less sensitive to feedstock composition characteristics. Without reducing feedstock costs and improving biomass consistency, it is difficult to see a viable pathway to both achieving the DOE/BETO 2030 goal of $2.50/GGE (2016$) using an industrially relevant feedstock and competing on a cost basis with oil selling at less than $50 bbl. This project fulfills a critical role for DOE by developing supply system designs, delivered feedstock cost and volume targets, and forward-looking analyses to track R&D progress and guide the direction of R&D toward the highest-impact operations. 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 barriers Ft-A: Terrestrial Feedstock Availability and Cost and Ft-M: Overall

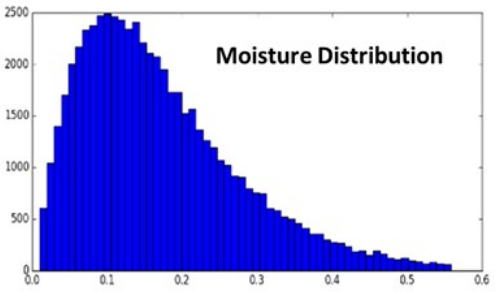
Weighted Project Score: 8.3

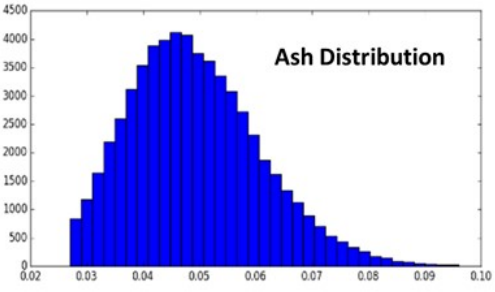
Weighting for Ongoing Projects: Approach-25%; Accomplishments and Progress-25%; Relevance-25%; Future Work-25%



I One standard deviation of reviewers' scores

Integration and Scale-Up. This project develops and vets innovative strategies that meet cost, quantity, and quality specifications while minimizing environmental impacts and delivering robust data sets with flexible analysis tools to enable industry to implement a successful biofuel supply system. This project also tracks technology progress based on technology improvements identified and verified annually in R&D activities. Historically, we have investigated both conventional feedstock supply systems and a number of advanced (active quality management) feedstock supply system strategies, including blending and commoditizing biomass to meet modeled cost, quantity, and quality specifications required to meet long-term U.S. biofuel production goals. Complete field-to-reactor throat feedstock supply infrastructures and systems are analyzed, including, but not limited to, innovative harvest and collection equipment, advanced preprocessing technologies, biomass composition variability, and the interface between feedstock variability and conversion performance. This project leads the development of the pathway to the 2022 Multi-Year Plan (MYP) target for the development and verification of feedstock supply and logistics systems that can economically and sustainably supply industrially relevant quantities of herbaceous feedstocks for biochemical conversion at a delivered cost no more than $85.51/dry ton (2016$), and contribute to meeting a delivered feedstock cost target of $71.26/dry ton, in support of achieving the $2.50/GGE minimal ethanol selling price target for 2030. Finally, this project develops new computational tools to advance the state of the art in feedstock supply and preprocessing modeling capabilities. Examples include continual updates to the Idaho National Laboratory (INL) Biomass Logistics Model, new analysis tools to enable dynamic simulation of throughput and operational performance, and feedstock supply and preprocessing system optimization tools that simultaneously consider multiple aspects of delivered biomass quality and supply.





Equipment Performance

First Stage Grinder	
Regular Failure	
Mean time to failure	6 months
Mean repair time	2 hours
Repair time standard deviation	30 minutes
Ash Caused Failure	
Cumulative ash processed	500 tons
Mean repair time	6 hours
Repair time standard deviation	2 hours
Moisture Caused Failure	
Maximum moisture content	35%
Mean repair time	30 minutes
Repair time standard deviation	15 minutes

Equipment Down Time – 1-year Discrete Event Simulation (DES)

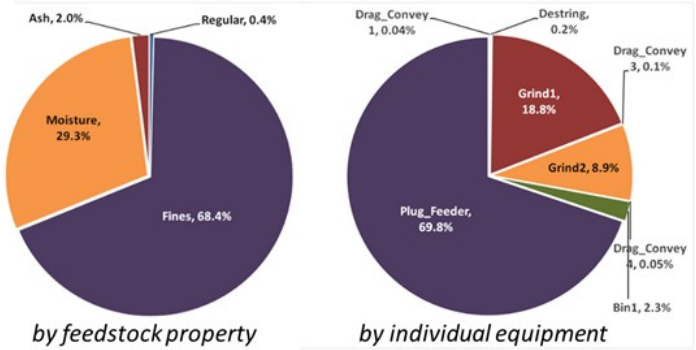


Photo courtesy of Idaho National Laboratory

OVERALL IMPRESSIONS

- In summary, managing the information in presentations such as this—where information comes from many diverse sources, programs, and in different formats—is a difficult task. As a reviewer, after the goals, sometimes I would like to see approach sections (both managerial and technical), then take one key goal/milestone and describe the process in great detail, including how mitigation were steps, if any; how gaps were identified and filled; and what the thought process was. Then state whether the other goals and milestones were met or not and where to find additional information should we wish to see it.

That way, I could make more informed decisions about the strengths and weaknesses of the project and presentation.

- TEA is key metric for all BETO research, and as such the importance of this project cannot be questioned. The project did a good job of incorporating new SOT concepts, such as depot and wet pelleting (as well as FCIC changes, such as inclusion of process variability). For future peer reviews, I suggest picking an example—good or bad—and showing how it goes through the project cycle, including touch points with different projects and team members. This would help reviewers understand the actual project approach.

- The project has met the demands of the FSL/FCIC project needs, and an evaluation of different control strategies has been executed (bale rejection, et al.); thus, the TEA is being used as more than only as a metric—it is being used to help define processing strategy. It was not completely clear from the presentation how these scenarios are brought into the analysis process. Consider whether more visibility and clarity here could bring more clever ideas from outside the project team members.

- This project has a long history of providing valuable analytic support to BETO for use in developing strategic MYPs. The proposed plans are very well in tune with analysis and planning needs identified by BETO. The individuals involved at several DOE labs have developed analysis expertise that can be called upon to provide quick responses to questions from Congress, industry, and the general public. This is a resource that should have value not only to BETO but also to other DOE offices and potentially to specific commercial project development activities.

- Modeling work such as this project helps identify missing information and guide new research.

- This feedstock quality and cost modeling project integrates the available modeling and SOT work to inform BETO and other users of progress toward goals and identify challenges to overcome.

RECIPIENT RESPONSE TO REVIEWER COMMENTS

- We understand the reviewers' perspective. This project supplies system TEAs for all conversion technology platforms that use terrestrial feedstocks. This is in contrast to the majority of BETO's TEA projects, which typically focus on single conversion processes. This currently amounts to four different feedstock supply chains, which makes it difficult to cover any in detail in the allotted time and provide a good overall picture of the breadth and scope of the project's accomplishments and impacts. Unlike other TEA projects that use standard packages such as Aspen Plus and CHEMCAD to perform their analyses, we must continually develop and upgrade analysis tools to perform our analyses (progress on which is tracked by additional milestones). Developing these tools is an accomplishment in and of itself because the resulting ability to model something that was not heretofore possible to model has substantial impact on the ability of BETO to understand what must happen to successfully develop a robust bioeconomy. A good example of this is the throughput analysis approach and model developed by this project, which brought to the forefront the operational issues than can be attributed to feedstock quality variations.

- Design cases are developed approximately every 5 years that lay out the expected technology development pathways that are needed to achieve BETO program goals and targets during the next period. The design cases are developed with participation of the R&D project PIs, and then supply system analysis is used to model the impacts of technology improvements toward the technical targets. Annual SOT reports track R&D progress toward individual technology targets as well as the overall supply system targets.

SUPPLY FORECASTS AND ANALYSIS

Oak Ridge National Laboratory

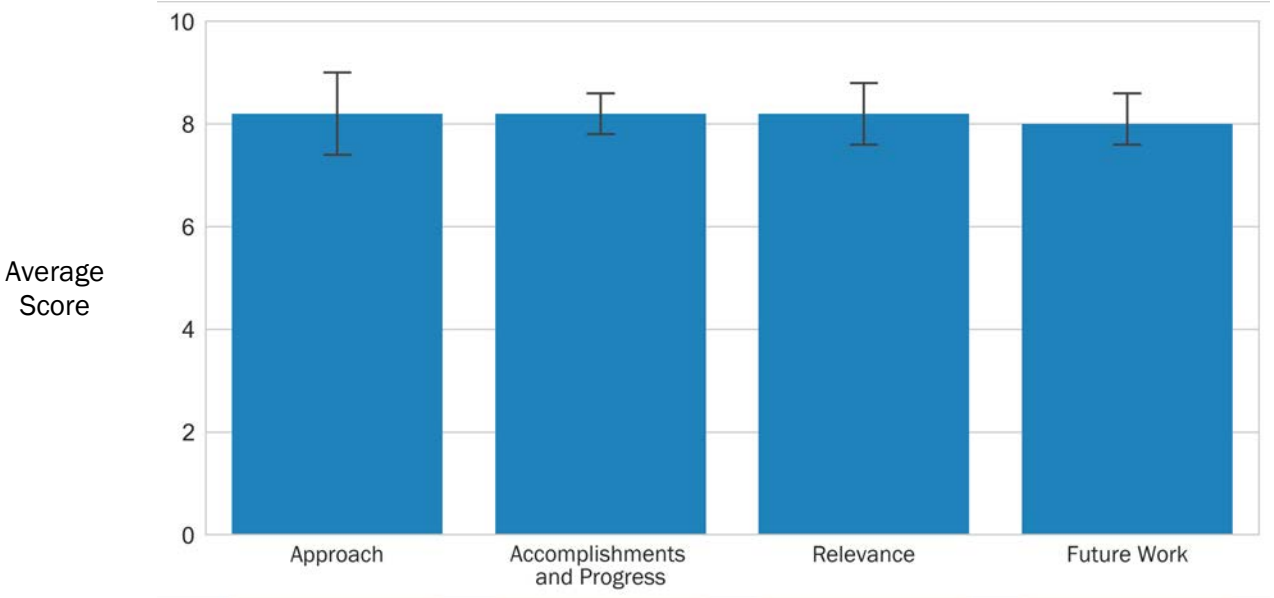
PROJECT DESCRIPTION

WBS:	1.1.1.3
CID:	NL0015593
Principal Investigator:	Dr. Matt Langholtz
Period of Performance:	10/1/2017–9/30/2020
Total DOE Funding:	$1,875,180
DOE Funding FY16:	$0
DOE Funding FY17:	$0
DOE Funding FY18:	$1,375,180
DOE Funding FY19:	$500,000
Project Status:	Ongoing

The goal of the project is to provide DOE and bioeconomy stakeholders with biomass feedstock data needed to develop strategies to derisk the biomass supply chain. These data include information regarding biomass feedstock quantity and cost as well as environmental effects associated with producing, harvesting, and transporting biomass. Because these data can vary by feedstock type and spatial distribution, they should be generated under assumptions that reflect specified bioindustry scenarios. For example, biomass feedstock data should reflect the scenario-specific feedstock demand characteristics regarding type, quantity, and spatial distribution of feedstock required. Economies of scale from the position of the biorefinery, as well as "Nth-plant" mature-industry feedstock use, run counter to potential diseconomies of scale in feedstock supply. This project applies feedstock supply analytics to account for these scenario-specific feedstock supply attributes. Further, understanding the environmental effects of marginal additions of biomass in the United States or in a region—as well as the intersection of cost and environmental effects—can help DOE and bioeconomy stakeholders identify feedstocks and regions that constitute the best opportunities to grow biomass. We are examining the relationship between potential county-level agricultural and forest biomass supply and environmental effects in 2040, based on 1% and 3% yield growth scenarios from the *2016 Billion-Ton Report*, using a novel environmental supply curve visualization.

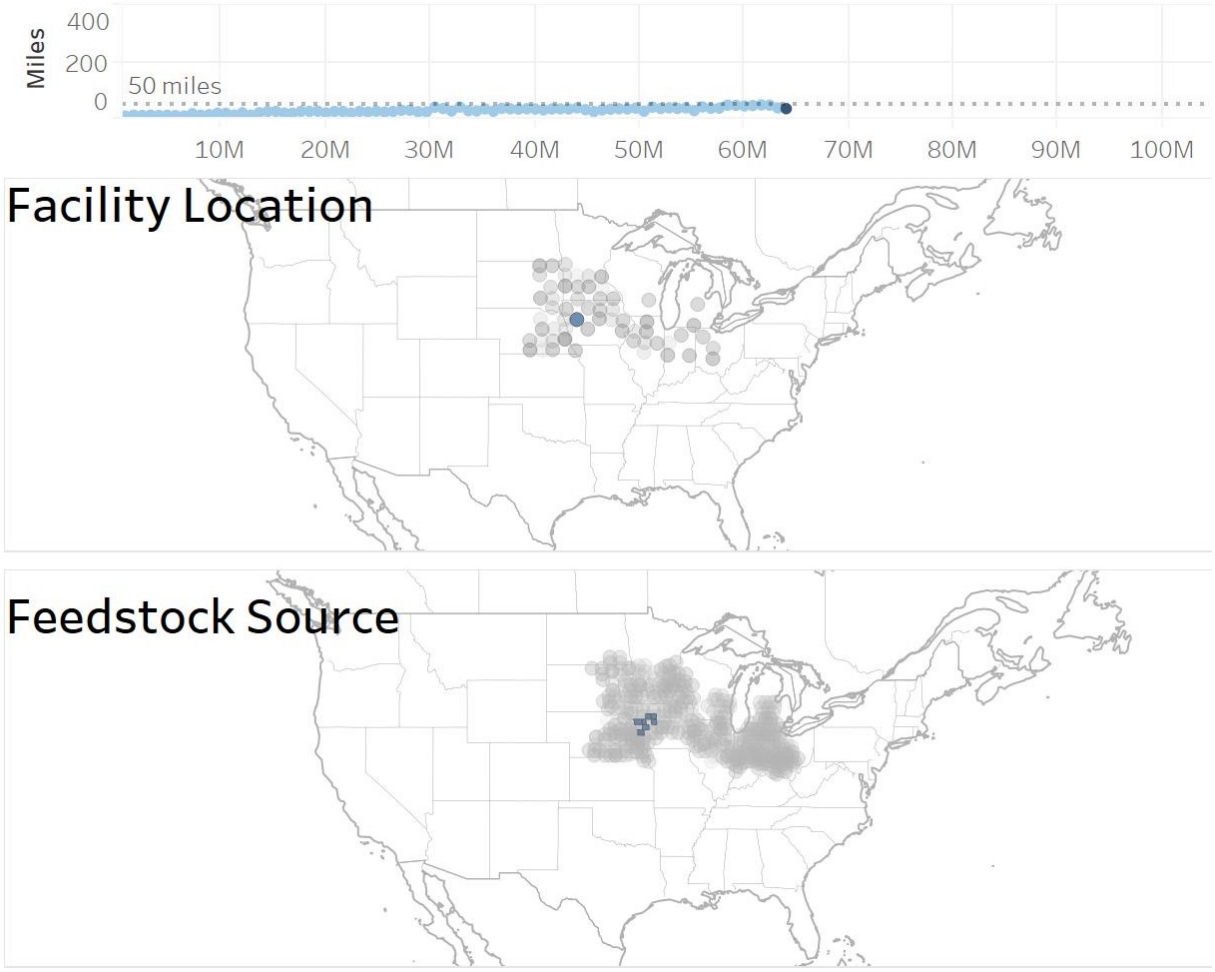
Weighted Project Score: 8.2

Weighting for Ongoing Projects: Approach-25%; Accomplishments and Progress-25%; Relevance-25%; Future Work-25%



I One standard deviation of reviewers' scores

An additional objective is to examine trade-offs or synergies between price and environmental effects as biomass supply, especially energy crops and residues, increases across the United States. Water quality and quantity, GHG emissions, air quality, and biodiversity outcomes are considered. Preliminary analyses have shown some synergies between price and reduced adverse environmental effects. For example, GHG emissions intensities are low for low-price corn stover, especially after logistics are included in the cost and environmental effects. Moreover, we identified regions where particulate emissions were high, and costs of production were among the highest in the United States. We also identified trade-offs between price and environmental effects, as in water and nutrient losses from soil to streams that coincide with the least expensive forest biomass to harvest. For water quality, we worked with A&S Project 4.2.1.40 to internalize some environmental externalities into total cost curves, showing the clear economic benefits of the water quality loading reductions associated with energy crops. Data visualizations were developed in Tableau data visualization software.



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OVERALL IMPRESSIONS

- Although I am fully in favor of such studies, I am always suspect of the assumptions behind the conclusions reached in the study about the price of the commodities in question, whether corn stover, switchgrass, forest residue, or clean wood chips, to name a few. I am not trying to question the validity

of the conclusions or the assumptions; I do not find enough information in the presentation about their source to decide.

- This is important work to understand the potential of the industry. The model's current detail is very impressive, and the tools that have been developed to suggest likely biorefinery sites are interesting. From the presentation, it was difficult to understand the full granularity of the variables included in the model, although it was evident it was rather expansive. Some factors to consider including in future work might be municipal readiness (i.e., road access) because this will often be tied to the capital project by local government, as well as gradual impact of climate change because it relates to the rollout of the plants, from pioneer to the n^{th}-plant, over some period of years.

- Despite what one might easily argue is the most comprehensive feedstock model short of oil exploration, the project specifically stopped short of saying the models should be used to site actual plants. The reviewer can appreciate liability impacts; regardless, either it will be used by industry or not, and if not, it might not be as valuable. Consider owning the accuracy of the model and the great work it is, and use it to actually go to some of the sites and understand how well your model captures what would be the actual logistics and local support of a plant located where the model predicts.

- The development of sophisticated analysis methodologies and the results published in the three previous *Billion-Ton* reports have made a very strong contribution to the development of MYPs and strategies by BETO. The recent focus on scenario and specific end use locations is a very valuable addition. Future work plans are well in tune with R&D needs identified by BETO. The goal of making the outputs of the work available to several other BETO projects has been clearly accomplished. The individuals involved—from several DOE labs and a university—have developed analysis expertise that can be called upon to provide quick responses to questions from Congress, industry, and the general public. Downloads of the data shared in public databases have been very high, but finding a way to also share the expertise developed by the analysts with project developer stakeholders would also be valuable.

- This project has a national scope and is foundational to biomass feedstock supplies and logistics.

- This spatially based feedstock quantity and cost modeling project is useful to biorefinery developers as well as policymakers. It will integrate well with other BETO modeling projects as well as growth and yield databases.

RECIPIENT RESPONSE TO REVIEWER COMMENTS

- The reviewer's suspicions of reported prices are understandable given the limited detail provided during the peer review presentation. Technically, we do not consider cellulosic biomass resource commodities because quality specifications have not been widely accepted for commoditization; however, methods and assumptions of the economic modeling were reviewed by more than 30 external reviewers from industry, government, and research sectors. The assumptions and the review process are described in the *2016 Billion-Ton Report* (http://energy.gov/eere/bioenergy/2016-billion-ton-report). Further, methods used in the report are applied in various peer-reviewed manuscripts. Acknowledging prices are impossible to predict with certainty because future macroeconomic and technical innovations are impossible to predict.

- We appreciate the reviewer's suggestions regarding municipal readiness, climate change, and explicitly characterizing accuracy.

SENSORS AND MEASUREMENT IN HARVEST & COLLECTION FOR RAPID QUALITY CONTROL OF CORN STOVER

Idaho National Laboratory

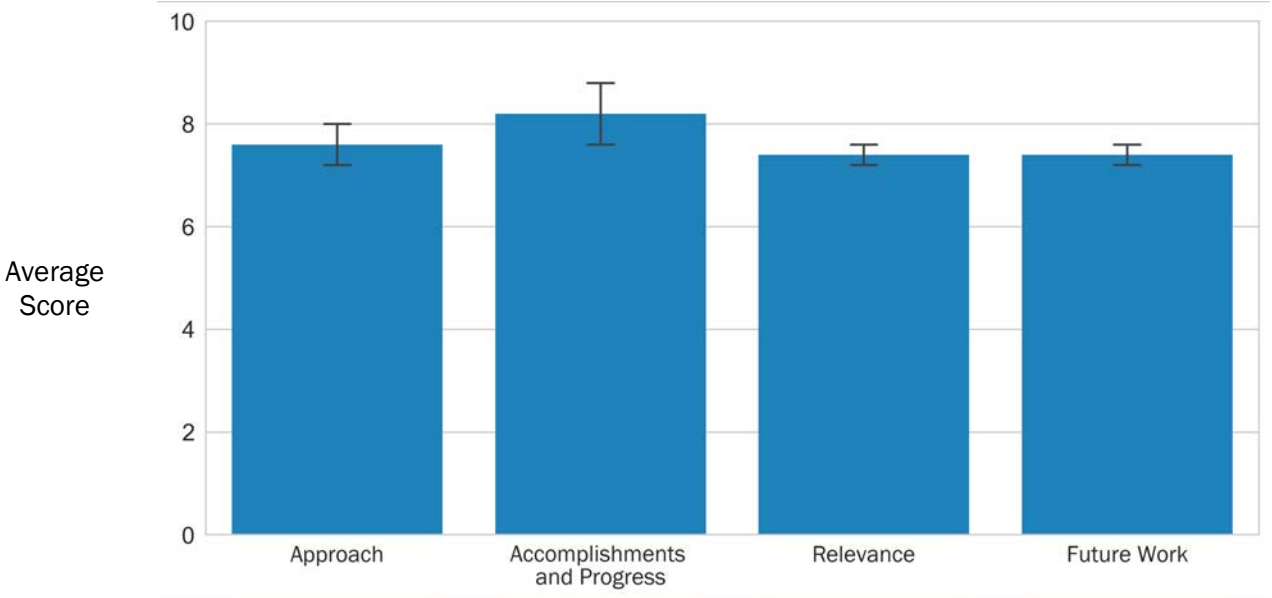
PROJECT DESCRIPTION

WBS:	1.2.1.1
CID:	NL0015076
Principal Investigator:	Mr. Bill Smith
Period of Performance:	10/1/2015–9/30/2021
Total DOE Funding:	$5,021,373
DOE Funding FY16:	$1,190,000
DOE Funding FY17:	$1,190,000
DOE Funding FY18:	$1,716,373
DOE Funding FY19:	$925,000
Project Status:	Ongoing

Results from pioneer integrated biorefineries and research at INL show negative impacts of moisture and soil content in baled biomass. Impacts include biological degradation, displacement of valuable biomass components by soil, and increased preprocessing and handling costs. Existing harvesting and storage practices have proven ineffective at reducing bale-to-bale variations in moisture and ash from soil content that occur in commercially harvested corn stover delivered throughout the year to a biorefinery. The project goal is to demonstrate the major components of an information-driven biomass supply design that has potential to reduce harvesting- and storage-related quality variations in delivered biomass between annual harvesting operations. Components include: (1) in-field and in-storage characterization of moisture, carbohydrate, and ash using a novel near-infrared (NIR) spectroscopic bale probe, (2) storage stability prediction based on measurable biomass and environmental conditions, and (3) a logistics management algorithm incorporating yearlong storage performance that selects lots for periodic delivery based on user inputs such as target moisture and carbohydrate content. Storage performance—i.e., moisture migration and dry matter stability—will be characterized based on physical and computational models of heat flow, multiphase moisture dynamics, and biological activity in storage. Research products include improved NIR spectroscopic analytic methods for

Weighted Project Score: 7.7

Weighting for Ongoing Projects: Approach-25%; Accomplishments and Progress-25%; Relevance-25%; Future Work-25%



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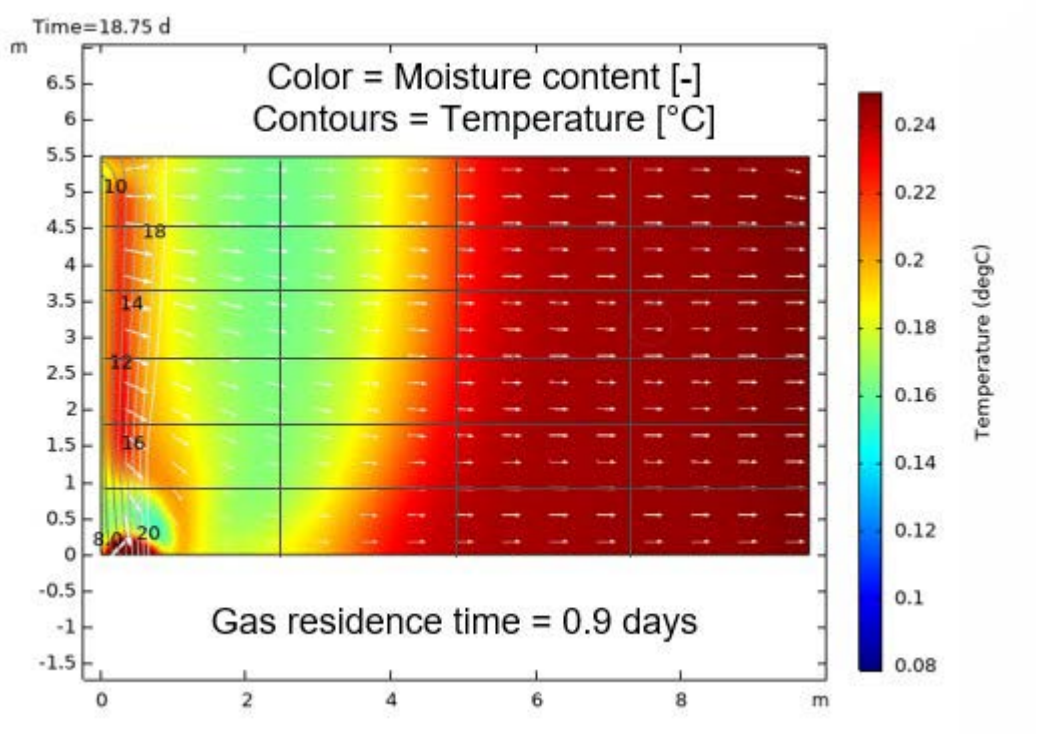
total ash in baled corn stover using INL's bale probe; development of laboratory-proven "first-principles" models describing storage performance; and demonstration of a logistics system design that uses composition, storage performance projections, and climate data to reduce composition variations over time. Results to date show that changes in biomass composition over time can be anticipated and managed to reduce temporal variations in moisture, carbohydrate content, and ash as a result of carbohydrate loss using a simplistic model of storage performance; however, more complex models are needed to evaluate commercially relevant storage conditions in and outside of the U.S. Corn Belt. The complexities of commercial storage systems include variations in biomass composition anatomical fractionation resulting from harvesting operations, interactions between stacked bales and the ground surface storage pad, weather climate conditions, and potential storage improvements such as active and passive ventilation. Ongoing work aims to evaluate the physical, chemical, and biological phenomena driving biomass storage stability relative to moisture dynamics (wetting/drying) and biological activity (dry matter preservation); create computational models to test our understanding of these phenomena; and develop means to employ these principles to reduce temporal variations in delivered biomass quality during a year's storage period.



Photos courtesy of Idaho National Laboratory

OVERALL IMPRESSIONS

- Overall, this is a well-executed project thus far, with promising results that should pay off in helping industry create better handling and preprocessing system designs. There are two areas I wish the presentation and project performers would have taken time to explore, however: (1) the current economic estimates of the economic effects of the work and (2) the early potential design characteristics that are developing or what problems the designs need to solve.

- This is a very impactful set of work to date that creates a lot of deeper understanding on how bale storage impacts quality parameters. NIR probe work has been very important and valuable to increasing the understanding of how bales store. That said, the reviewer is concerned that mitigation techniques are not clearly defined in the project scope. Ideally, outcome of the future work would educate on how to maximize storage stability (i.e., new storage practices) or illustrate a method for removing poor-quality portions from the bale or bale lot.

- It was not clear how the NIR probe testing would be scaled up, although that seemed to be one aim of the work. Consider how red-scale/infrared scans could be correlated with actual probe data such that drones or other noninvasive approaches could be used to grade bales/bale lots.

- This project involves a lot of fundamental research but promises to address and demonstrate very practical solutions to current problems in the types of herbaceous residue handling activities that are likely to be the most common in near-term commercial activities. This fundamental research project is also focused on the end goal of obtaining industry adoption of the fundamentals being researched (ash/moisture avoidance practices, analytic tools, and biomass storage management practices/tools). The close linkage between this fundamental research project and the FDC Enterprises field demonstrations of advanced supply chain practices is a great example of focused, goal-oriented R&D. The substantial amount of data presented shows that the project is progressing nicely, but actual progress toward the end of the project goal is difficult to assess at this time.

- Fast physical biomass characterization is important to suppliers when they are paid on a dry-ton basis.
- This project has succeeded in developing the tools and models to understand the moisture and dry matter dynamics of baled stover. This is helpful to inform the storage and use of this feedstock at biorefineries. Next steps should include expanding this work to include other baled feedstocks.

RECIPIENT RESPONSE TO REVIEWER COMMENTS

- The project team thanks the review panel for their time and thoughtful comments. We have worked extensively throughout the project lifetime to understand the largest cost drivers in harvest, collection, and storage operations. Under best-case scenarios, storage costs as low as $6.41/t have been reported within this task previously and are reflected in the analyses of INL's Feedstock Supply Chain Analysis task (WBS: 1.1.1.2). Best-case storage scenarios are not always a reality, however, and excess moisture in bales occurs for several reasons, including harvest timing, field conditions, and climate. The current research goals of this project focus on optimizing storage conditions to reduce the variability and improve downstream reliability as biomass enters preprocessing, which ties closely with the goals of the FCIC. To that end, this task has focused on two reported challenges: (1) variations in bale moisture content, especially at the upper end of moisture content; and (2) degradation that occurs as a result of high moisture content over time. Our supply system designs focus on enhancing bale drying rates in storage—early, before biodegradation occurs—through cost-effective means. These include using naturally occurring wind patterns through informed site selection and stack configuration, using microbial-generated heat to increase internal stack temperatures to enhance drying, using multiple storage methods to balance storage cost and storage performance, and using predictive models based on physical and biological properties to identify which lots should be delivered at what time to minimize compositional variations and maximize the value of the harvested biomass.
- Integral to this research effort is the NIR spectrometric probe, which was developed to overcome the challenges of within-bale variations in biomass composition and the need for rapid biomass analysis. This scope was transferred to this project from the BETO-funded Biomass Alliance for Logistics Efficiency and Specifications (BALES) High-Tonnage Logistics II project in FY 2019. We agree with the reviewer's comments regarding corn stover, and in FY 2020 we plan to expand the use of this tool to include baled switchgrass. Lessons learned in corn stover and switchgrass will be applied to expanding the number of commercially relevant baled and bulk biomass feedstocks beyond FY 2022. Although the current programmatic shift to more fundamental technical research might not permit INL to focus on the physical probe deployment and pilot-scale storage experiments, we will continue to work closely with external partners to develop robust and efficient means of probe application and confirmation of laboratory- and bench-scale results regarding storage stability and moisture migration in storage.
- We will continue to apply the tools that this project is developing, such as the NIR probe and the storage and queuing models, to anticipate and minimize variability such that high-quality biomass can be provided for preprocessing and conversion.

DEVELOPMENT OF A WET LOGISTICS SYSTEM FOR BULK CORN STOVER

Idaho National Laboratory

PROJECT DESCRIPTION

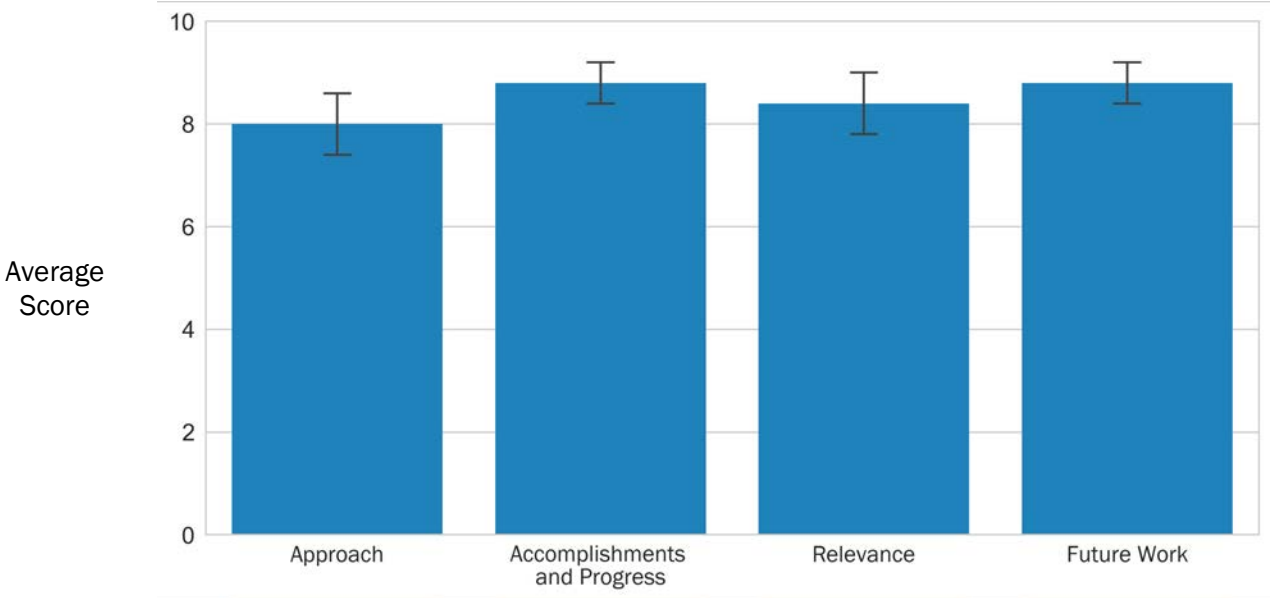
WBS:	1.2.1.1000
CID:	NL0028567
Principal Investigator:	Ms. Lynn Wendt
Period of Performance:	10/1/2014–9/30/2020
Total DOE Funding:	$1,938,454
DOE Funding FY16:	$667,250
DOE Funding FY17:	$385,000
DOE Funding FY18:	$501,204
DOE Funding FY19:	$385,000
Project Status:	Ongoing

The feedstock logistics supply chain relies on storage to supply conversion facilities year-round given that most biomass sources are only seasonally available. An estimated 60% of available corn stover is projected to be harvested at moisture contents that exceed 20% wet basis, making it susceptible to microbial degradation when stored aerobically. Likewise, corn stover bales are at risk of catastrophic loss by fire, as evidenced by bale yard fires at biorefineries. Active management approaches in the feedstock logistics supply chain, specifically the use of high-moisture storage, can protect feedstock from loss caused by fire or microbial degradation. Wet logistics systems using anaerobic storage to provide stable storage and can be used to enable the nation's billion tons of biomass. Two barriers to large-scale storage operations include predicting storage performance at commercial scales and predicting the impact of wet storage biomass to biochemical conversion approaches. This project explores the possibility of storage add value by reducing biomass recalcitrance.

To understand the degradation potential in biomass stored under such conditions, we developed a numerical model that mathematically represents the gas and heat-transfer processes controlling dry matter loss and

Weighted Project Score: 8.5

Weighting for Ongoing Projects: Approach-25%; Accomplishments and Progress-25%; Relevance-25%; Future Work-25%

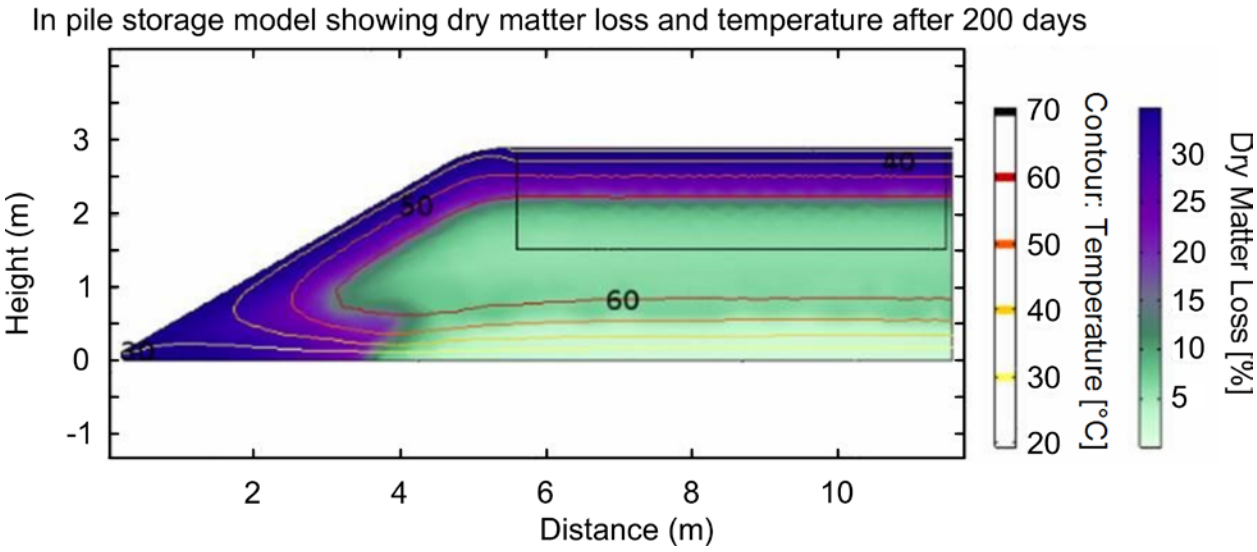


I One standard deviation of reviewers' scores

temperature in storage sites. This model was then tested against field data from a 500-t storage study using 40% moisture corn stover. With primary inputs based on laboratory-measured dry matter consumption rates, heat- and gas-transfer properties, and on local meteorological data, the model reproduces many primary observed trends in field data, specifically temperature and gas concentrations as well as dry matter loss over 6 months. The resulting model appears to provide an excellent means of testing how changes to storage conditions would likely affect storage performance. As storage bulk density decreases and porosity increases, for example, temperature and degradation increase. This effort demonstrates the impact that storage conditions could have on performance under commercially relevant settings.

Biochemical conversion approaches rely on pretreatment and enzymatic hydrolysis to create sugar monomers that can be fermented into biofuels. Aerobic and anaerobic storage methods were evaluated for wet corn stover in laboratory reactors as well as in the field. Assessment of sugar release as a result of dilute acid or dilute alkaline pretreatment and subsequent enzymatic hydrolysis suggested that when anaerobic conditions were maintained in storage, sugar release was either similar to or greater than as-harvested material depending on the pretreatment chemistry used.

The use of agricultural residues, which are harvested seasonally, necessitates storage to supply a biorefinery with a consistent feedstock supply year-round. The long residence time of storage offers an opportunity to perform low-severity treatments that can have benefits downstream. In-storage treatments can reduce costs and energy consumption of mechanical preprocessing and pelletization, chemical pretreatments, and enzymatic hydrolysis of complex carbohydrates. To accomplish this, we are using biological and chemical treatments that use the long residence of storage to begin to break down biomass components—including acetyl and hemicellulose as well as lignin—thus resulting in a feedstock that is less recalcitrant. Both fungal treatment and alkali treatment combined with a 1-month storage duration were shown to increase extractable compounds in the biomass and have promise to indirectly add value to the biomass in the storage operation. The overall product of this research will be performance data for a range of potential methods to add value in the supply chain. This research also addresses multiple MYP barriers and contributes to the $2.50/gal goals.



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OVERALL IMPRESSIONS

- Wet storage of biomass is a great area for DOE/BETO to fully understand, most notably the cost implications as potential value addition is balanced against increased handling costs. An understanding of the current negative cost state suggests that some discussions of the cost development pathway

screening to accompany the characterization pathway need to occur with adjacent FSL projects in the portfolio, perhaps resulting in integration of some concepts to mitigate risks associated with each.

- Wet storage treatments have the potential to help normalize feedstocks/blends in support of creating fungible feedstock.

- This project is a valuable contribution to the BETO portfolio because it is developing economically viable methods to manage high-moisture feedstocks to produce biofuels and bioproducts. The approaches are well described, and the presentation shows that substantial new information has been generated that could be very useful to potential project development. Addressing the potential for using the storage period to partially pretreat the biomass is very positive with exciting impacts. Scaling up the research is a logical and valuable future work activity. The fact that an industrial partner is already working on demonstrating the value-added approach is a great success story at this stage in the value-added component of the project.

- Wet bulk storage systems could return to the forefront with new approaches to address dry matter loss and feedstock quality.

- This is one of the most relevant projects in the FSL portfolio. Success here will solve several of the most pressing problems around feedstock variability, at least regarding corn stover and other materials with similar qualities. In turn, this would encourage the investment in and building of projects to advance BETO objectives according to the MYP. There was a good explanation of the applications for the development of a full commercial-scale storage yard. I am not sure the PIs have thought through other indirect impacts that this work could have on other parts of the overall enterprise of a cellulosic biorefinery. With the ability to bale wet material, the current SOT in baling operation costs could be cut by 10% or more; and if advanced harvest and baling were used, by as much as 50%. Advanced baling methods would also reduce the ash content of corn stover and in turn solve another of the most pressing impacts caused by feedstock variability.

- This well-designed project has applied principles of ensiling to the storage of corn stover and succeeded in building a model for biorefineries to use when planning their storage systems. Significant progress has been made on using the wet storage of this material to the advantage of certain end-use processes.

RECIPIENT RESPONSE TO REVIEWER COMMENTS

- The project team thanks the review panel for their time and thoughtful comments. We have worked extensively during the project lifetime to understand the largest cost drivers in harvest, collection, and storage operations. Under best-case scenarios, storage costs as low as $6.41/t have been reported within this task previously and are reflected in the analyses of INL's Feedstock Supply Chain Analysis task (WBS: 1.1.1.2). Best-case storage scenarios are not always a reality, however, and excess moisture in bales occurs for several reasons including harvest timing, field conditions, and climate. The current research goals of this project focus on optimizing storage conditions to reduce the variability and improve downstream reliability as biomass enters preprocessing, which ties closely with the goals of the FCIC. To that end, this task has focused on two reported challenges: (1) variations in bale moisture content, especially at the upper end of moisture content; and (2) degradation that occurs as a result of high moisture contents over time. Our supply system designs focus on enhancing bale drying rates in storage—early, before biodegradation occurs—through cost-effective means. These include using naturally occurring wind patterns through informed site selection and stack configuration, using microbial-generated heat to increase internal stack temperatures to enhance drying, using multiple storage methods to balance storage cost and storage performance, and using predictive models based on physical and biological properties to identify which lots should be delivered at what time to minimize compositional variations and maximize the value of the harvested biomass.

- Integral to this research effort is the NIR spectrometric probe, which was developed to overcome the challenges of within-bale variations in biomass composition and the need for rapid biomass analysis. This scope was transferred to this project from the "BALES" High-Tonnage Logistics II project in FY 2019. We agree with the reviewer's comments regarding corn stover, and in FY 2020 we plan to expand the use of this tool to include baled switchgrass. Lessons learned in corn stover and switchgrass will be applied to an expanding number of commercially relevant baled and bulk biomass feedstocks beyond FY 2022. Although the current programmatic shift to more fundamental technical research might not permit INL to focus on physical probe deployment and pilot-scale storage experiments, we will continue to work closely with external partners to develop robust and efficient means of probe application and confirmation of laboratory- and bench-scale results regarding storage stability and moisture migration in storage.
- We will continue to apply the tools that this project is developing, such as the NIR probe and the storage and queuing models, to anticipate and minimize variability such that high-quality biomass can be provided for preprocessing and conversion.

SIZE REDUCTION, DRYING, AND DENSIFICATION OF HIGH-MOISTURE BIOMASS

Idaho National Laboratory

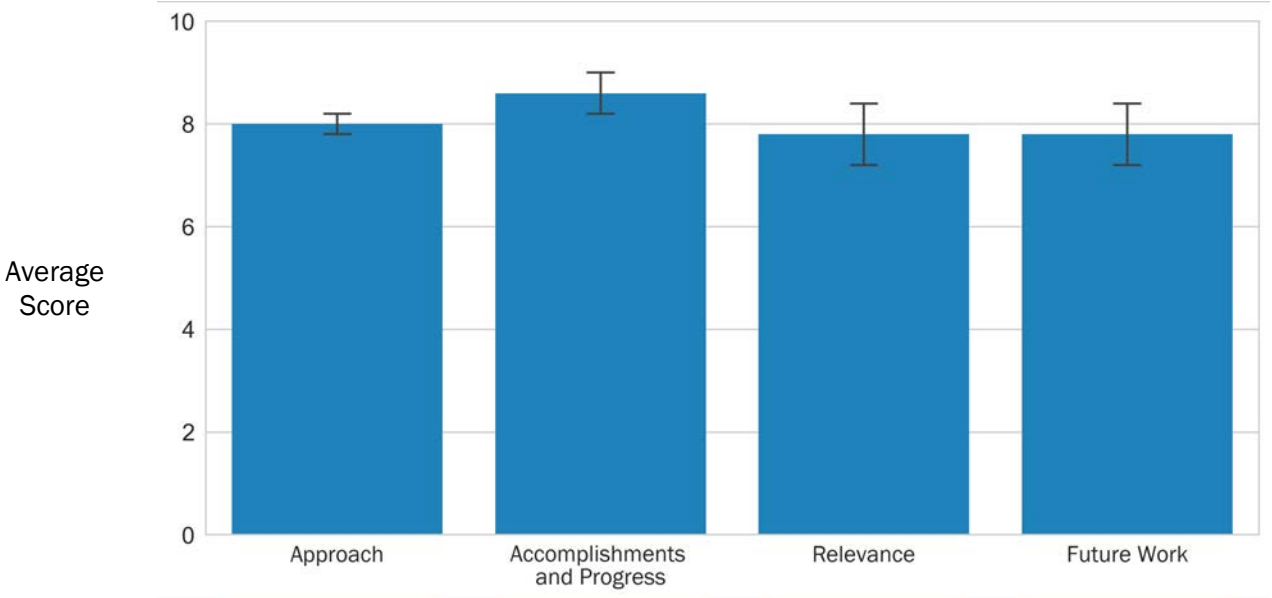
PROJECT DESCRIPTION

WBS:	1.2.1.2
CID:	NL0026654
Principal Investigator:	Dr. Jaya Tumuluru
Period of Performance:	10/1/2015–9/30/2020
Total DOE Funding:	$4,856,804
DOE Funding FY16:	$1,232,500
DOE Funding FY17:	$1,232,500
DOE Funding FY18:	$1,466,804
DOE Funding FY19:	$925,000
Project Status:	Ongoing

In FY 2017, the new processing technologies, fractional milling, high-moisture pelleting, and low-temperature drying were developed and demonstrated at the pilot scale using INL's process demonstration unit. TEA of the new technologies indicated that the corn stover pellet production cost was reduced by approximately 63% compared to a method that is currently followed by the pellet industry. High-quality pellets in terms of bulk density, 630–650 kg/m^3, and durability, 98.4%, were produced by the new technologies. The studies also indicated that efficient moisture management, high-moisture pelleting, and going for 7/16-in. screen in the Stage 2 grinder had a significant impact on processing cost. Several barriers still exist to deploying new pelleting technology to the biofuel and bioproduct markets. An INL National Renewable Energy Laboratory (NREL) annual operating plan project, FY 2017 2.2.1.102, and communications with industrial biofuel projects identified biomass particle attrition during preprocessing as a major issue for both biochemical and thermochemical conversion. Biomass particle attrition is the unintended size reduction that occurs during grinding and densification, resulting in the generation of increased fines. These fines are subsequently unrecovered in the downstream conversion processes. The INL NREL work showed an average mass loss of approximately 35% for corn stover pellets as a result of the generation of

Weighted Project Score: 8.1

Weighting for Ongoing Projects: Approach-25%; Accomplishments and Progress-25%; Relevance-25%; Future Work-25%



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fines in the range of 400 microns–425 microns. During FY 2018–FY 2020, the project is extending the state of the art in biomass pelleting with science-based solutions to improve pelleting efficiencies and to meet the desired quality specifications. The major impact of this project is that it makes pelleting an economically viable solution to solve feed handling, quality, and cost issues. The overall objective of the project from FY 2018–FY 2020 is to solve the particle attrition of corn stover during preprocessing and enable pelleting as a viable option to produce conversion-ready cellulosic feedstocks. This is achieved by conducting fundamental research that allows proper matching of process variables with material properties to minimize biomass residence time in the pellet mill. Innovation will occur through an improved scientific understanding of biomass flow and compaction in a pellet mill, which will lead to technology improvements to produce optimized pelleted feedstocks. The end of the project goal is to reduce particle attrition during preprocessing of corn stover by 80%, i.e., less than 7% fines, of 425 microns, compared to the current value, 35% fines. In FY 2018, pelleting tests were conducted using a single pellet press to understand the impact of the pelleting process conditions, e.g., compressive force from 7 kN–11 kN; preheating temperature, 70°C–110°C; residence time, 45–150 s; corn stover properties moisture content, 10%–20%; wet basis; and screen size of the grind, 1 4-in. and 7 16-in. Results indicated that reduced moisture content of 10% increased the particle attrition, whereas increasing the moisture content to 15% wet basis (w.b.) and 20% w.b. decreased the fines in the pelleted material. Also, the study indicated that increased residence times of particles, 150 s, increased the fines in the pelleted product. At 10% w.b. moisture content and 150-s residence time, 26% fines were found in the pellets produced using a 6.35-mm grind, whereas increasing the grind size to 11.11 mm decreased the fines values to approximately 16%–17 %. This study also indicated that the particle size distribution—mean particle size, D10, D50, and D90—in the corn stover pellets changes significantly with changes in the process variables. The optimized process conditions to minimize the fines in the pelleted corn stover to 12% were moisture content of approximately 20% w.b., 7 16-in. screen size of the grind, compressive force 9 kN, preheating temperature 90°C, and residence time of 45 s.

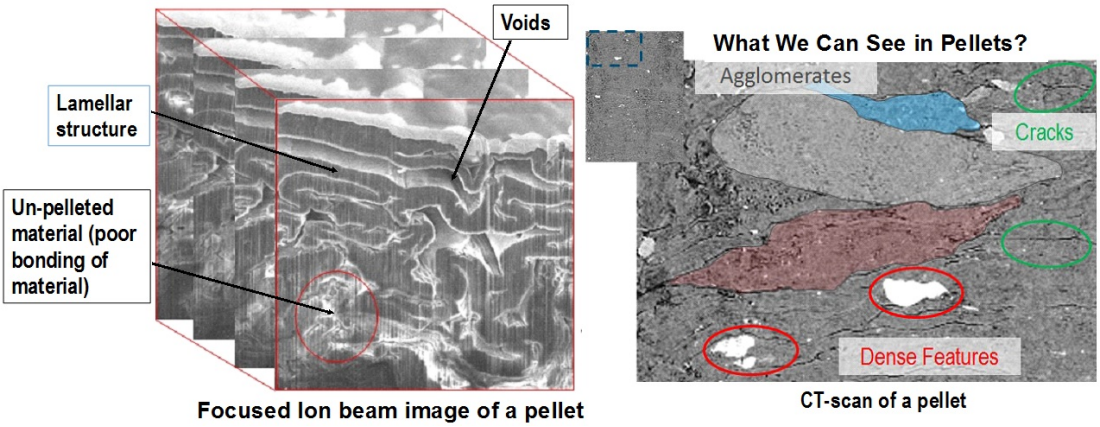


Photo courtesy of Idaho National Laboratory

OVERALL IMPRESSIONS

- Pelleting project relevance and success are notable, and the impact of process improvements is a key aspect of the biomass fungibility pathway. Congratulations. Great work by the project team.
- The reviewer would like to see some more diversity in the solution phase of the future work, especially regarding approaches to address the ash/fines issue. There are several industrial approaches to fines mitigation not presented that might be able to leverage even more added value to the process than the current state and future work plan.
- This very technical, narrowly focused project could be very useful to determining whether pellets can be an economically viable feedstock for bioenergy pathways. The research plan and implementation of the

plan has been excellent. The targets for the reduction of loss of biomass (particle attrition) were well defined, and clear progress has been made toward reaching those targets while providing valuable information about the feedstocks being studied and the composition of pellets. Future work on ash content removal is relevant. The presentation does not identify whether achievement of pellet technology improvement targets will result in making blended pellets economic at the total supply chain costs targeted by BETO.

- This project explores opportunities to reduce the cost of processing biomass while improving the quality.
- This is a very relevant project in the FSL portfolio. Success here will solve several of the most pressing problems around feedstock variability, at least regarding corn stover and other materials with similar qualities. Overall, I found the presentation to be informative about its goals, methodologies, and contribution to meeting BETO's goal of commoditizing high-quality biomass feedstock supplies; however, I find that the presentation is not detailed enough in its cost comparison because it compares only its cost to conventional pelleting processes. It should also consider avoided costs to current pretreatment methodologies at an integrated biorefinery research facility. In addition, I am not sure that the PIs have thought through other indirect impacts that this work could have on parts of the overall enterprise of a cellulosic biorefinery. If you could bale wet material, the current SOT in baling operation costs could be cut by 10%; if advanced harvest and baling were used, costs could be reduced by as much as 50%. The wide adoption of technology will occur only as we understand how it provides overall economic benefit to the industry it is addressing, which in this case is advanced cellulosic fuels and chemicals.
- This project is succeeding in demonstrating, at the pilot scale, how corn stover pelleting costs can be reduced and pellet quality can be improved through innovative drying, grinding, and compression methods.

RECIPIENT RESPONSE TO REVIEWER COMMENTS

- In FY 2020, we plan to collaborate with INL BETO projects that use chemical and microbial pretreatment methods for additional solutions to the fines issue during mechanical preprocessing. Mechanical methods such as fractionation and milling and mechanical separation techniques will be used to understand how various fractions, as well as the separation of fines in corn stover, impact the fines generation during grinding and pelleting. In FY 2020, we will explore chemical and microbial pretreatments methods tested in WBS 1.2.1.1000 (INL storage project), which can help remove most of the fines generating biomass components. We are working with the INL analysis team (WBS 1.1.1.2) to understand the technical and economic impact of using the fines that are generated during preprocessing for biochar production (which has a higher value as a soil amendment).
- The work focuses on improving the quality of the pellets for more reliable conversion performance. Even though pelleting enables many valuable logistics benefits that include storage, handling, and transportation, biomass particle attrition or fines in the product is a major impediment to the downstream conversion processes. INL reliability models also indicated that material properties such as bulk density, particle size distribution, and fines generated during preprocessing have a large impact on the feedstock supply cost to the biorefineries. The data generated in this project will be fed to the supply chain cost models developed in the project (WBS: 1.1.1.2). Also, we would like to clarify that in this project we are evaluating corn stover pellets, not blended pellets.
- Our INL analysis team analyzes the feedstock cost provided to a biorefinery by considering the feedstock supply, harvesting, storage, preprocessing, and transportation costs. The various projects in the FSL portfolio provide this information. We will work with our analysis team to consider in the SOT the impact of baling wet material and the impact of advanced harvesting and baling systems on the total cost of the feedstock provided to the biorefinery.

RESOURCE MOBILIZATION (THROUGH COMMODITIZATION AND TRADE)

Idaho National Laboratory

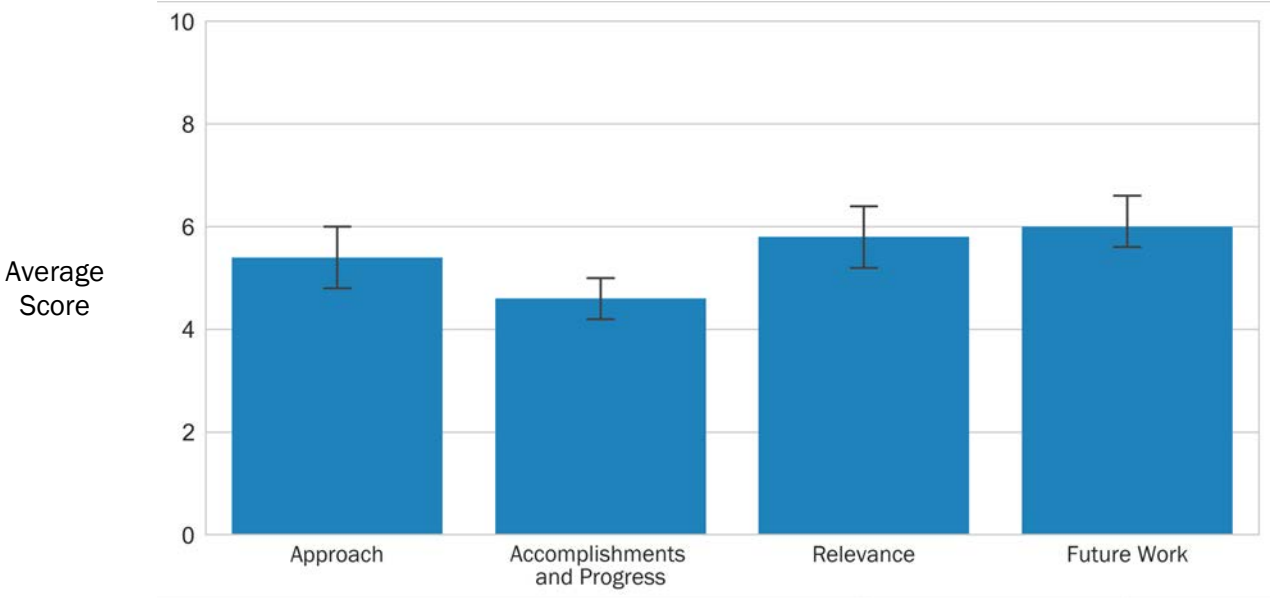
PROJECT DESCRIPTION

WBS:	1.2.1.5
CID:	NL0020844
Principal Investigator:	Dr. Damon Hartley
Period of Performance:	10/1/2015–9/30/2020
Total DOE Funding:	$1,086,340
DOE Funding FY16:	$255,000
DOE Funding FY17:	$255,000
DOE Funding FY18:	$321,340
DOE Funding FY19:	$255,000
Project Status:	Ongoing

Key factors hampering the establishment of a national biorefining industry are the high costs and uncertainties of setting up the underlying supply chains, with one of the largest risks being access to a reliable and consistent supply of biomass feedstocks. Currently, access to feedstocks is exacerbated by the lack of producers willing to supply feedstock materials because of the immaturity of the industry and the personal risks involved in the production of biomass feedstocks. Although the benefits of establishing a biorefining industry include providing jobs and economic revenue, neither of the main actors—grower or biorefineries—have the perspective needed to solve the problem. Inherent in the problem is the conflict of interest between the parties involved: growers want to maximize their profits with limited supply chain buy-in, and the biorefinery needs to reduce supply costs with very limited bargaining power. The development of this industry is incumbent on increasing the value proposition to the grower through innovative supply chain and contracting structures. New feedstock companion markets that have the characteristics of commodity goods will ultimately reduce both cost and risk to the biorefinery. Companion markets would share new supply chain infrastructure, invest in new technologies, and contribute to the reduction of supply chain risk. Therefore, incorporating companion markets into the biomass mobilization strategy would increase recovery and use of

Weighted Project Score: 5.5

Weighting for Ongoing Projects: Approach-25%; Accomplishments and Progress-25%; Relevance-25%; Future Work-25%



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all biomass fractions generated throughout the supply system and reduce supply costs to the biorefinery. Without the identification and development of mechanisms that drive the participation of growers into the development of feedstock supply chains, it will be nearly impossible to meet the BETO goal of fuel at $2.50/GGE by the year 2030. This project directly supports this BETO goal by examining and identifying the opportunities that exist to increase value to the grower through comarkets and coproducts and supporting the mobilization of the billion-ton resource base. Specifically, this project addresses the barrier identified by BETO as Ft-A: Terrestrial Feedstock Availability and Cost. This project provides credible, objective analyses of feedstock supply systems and strategies to support BETO investments in the development of a sustainable, economically viable national-scale bioenergy industry. Additionally, this project (1) identifies drivers and barriers to participation for growers potentially supplying biomass, and (2) informs the development of advanced feedstock supply systems through the development of forward-looking analyses. As a result, this project helps BETO to guide R&D toward targets and gauge progress on feedstock supply system improvements across various research areas. Moreover, this project provides an opportunity to evaluate the feedstock supply system barriers faced by an expanding bioenergy industry in the United States.

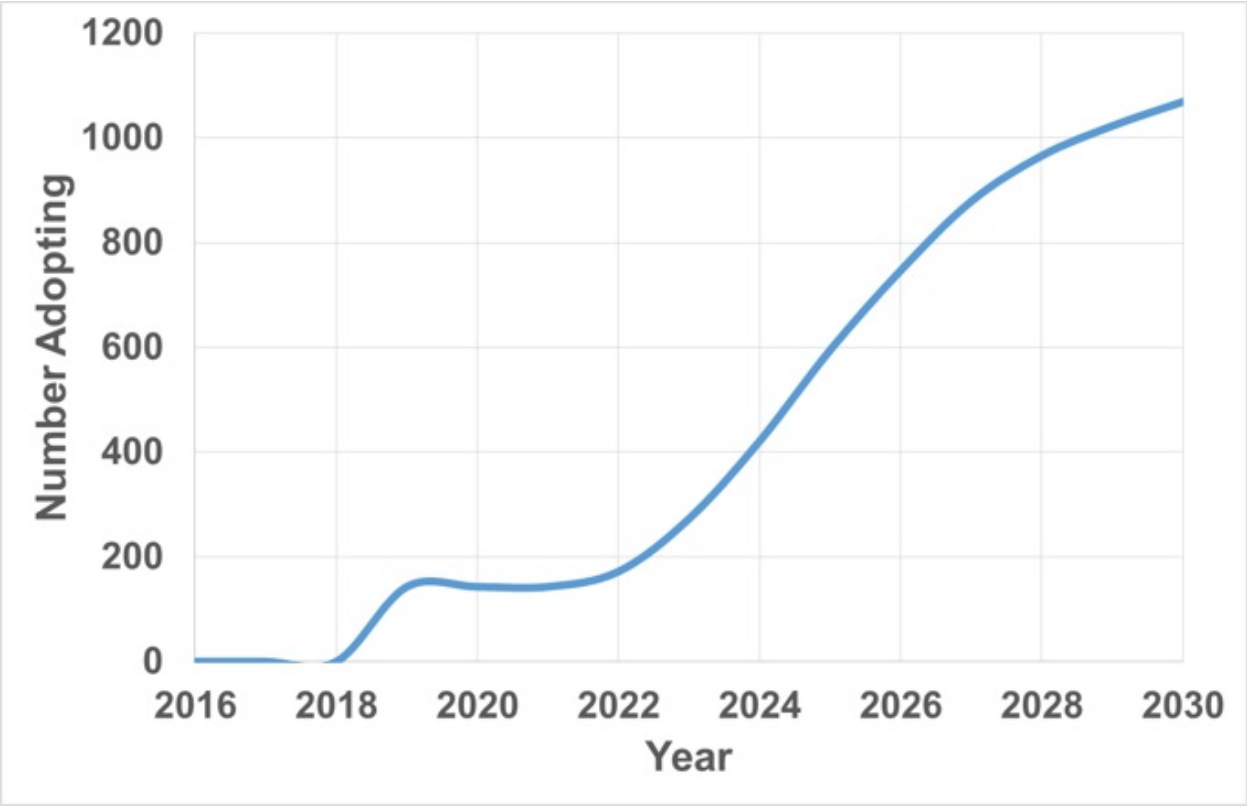


Photo courtesy of Idaho National Laboratory

OVERALL IMPRESSIONS

- This project's goal is to identify and model socioeconomic behavior that will suggest strategies to increase farmer/producer participation in the biomass supply chain to support a growing bioeconomy. More work is needed not only on suggesting strategies but also on how to implement these strategies. Farmers are innovative but also slow to change from practices used for generations, and this will prove to be challenging.

- This is a very important project/effort.

- Deeper understanding of socioeconomic impacts on the adoption of biomass production is very much needed. Answering such questions at the necessary local (for accuracy) and regional/national (for policy) levels is extremely difficult. The project approach to build models and continue to add layers is reasonable; however, as noted by several members of the review panel, decision-making methodologies of farmers—when a lower price is the target—are very vast and fluid. The project needs to include more experience in this space, perhaps via more direct USDA partnership and relevant industry suppliers, to be able to have models that can be used to enable any short-term advance in feedstock availability.

- Fungibility of feedstocks via the depot concept is a parallel approach that would drive a different set of socioeconomic drivers, and based on the SOT analysis seems a reasonable way to focus the efforts as well as simplify the modeling to provide more clarity for policyholders.

- The reviewer would like to see some beta test cases applied in the future to validate models and to initiate "practice" policy models.

- The project has a worthy goal of trying to explain and model how socioeconomic factors affect grower decisions to produce new crops or modify existing crop production strategies to provide reliable supplies of bioenergy feedstocks; however, it is difficult to understand how the proposed management and technical approaches will achieve that goal. The project claims to be using "innovative" methods to evaluate barriers and opportunities for mobilizing resources; however, graphic results are shown without any explanation of which methods were used to derive them. The information on supply push developments that could result from reduced European demand for pellets is interesting, but the relationship to describing grower participation in providing feedstock supplies is not well explained. It is very unclear how the project will be able to meet the go-no-go goal of producing meaningful scenarios of strategies that are likely to increase grower adoption.

- Willingness for growers to participate in a bioeconomy is a complex socioeconomic problem.

- This socioeconomic analysis of feedstock growers' participation in the bioeconomy is a critical piece of modeling that needs to be closely integrated with other supply models. Progress here and plans to integrate this model with others being developed needs to be more fully explained.

RECIPIENT RESPONSE TO REVIEWER COMMENTS

- We agree with the reviewer that the decision-making process employed by farmers is very heterogeneous and inconsistent depending on the scenario. We also agree that direct input from the producers and stakeholders is an invaluable resource when developing models like this. Throughout the project, we have been in contact with extension agents who work with the producers of bioenergy crops as well as businesses that are currently growing crops that could be used as bioenergy feedstocks. As the project continues, we plan to continue this dialog and hope to benefit from the knowledge gained through research projects such as the Sustainable Landscape Design (WBS 4.2.2.62), which is being led by the ANTARES Group and is collecting information about decision-making in terms of energy crops, directly from farmers.

- We are approaching the modeling in a stepwise approach in which behaviors and decision-making processes are being added to the model in a manner that allows for verification and validation. This type of modeling does not dictate the actions of the agent but rather institutes a set of rules that the agent must follow. Implementing the sets of behavioral rules in this stepwise manner allows us to ensure that the behavior that we have included in the model adheres to the specified rules and that the specification of the behavioral rules are manifesting behaviors that are reasonable.

- The presentation of this project represented two separate annual operating plan cycles, and between those cycles, the focus of the project morphed from a market analysis to a focus on the methods to affect

the adoption and implementation of bioenergy feedstocks. The information that was presented encapsulated two projects. Also, to represent all the work that had been completed, an overview of each was presented rather than a deep dive into a single topic.

- We agree that the impact of this project will be greater if the results are more fully integrated into the other modeling efforts; however the modeling that has occurred thus far has been different temporally. The modeling for the SOT projects is based on a mature industry, or n^{th}-plant scenario, and the feedstock supply analysis modeling is focused more on the potential that "could" realized given a set of future conditions and prices. The focus of this project is to try to understand the steps needed to attain the potential described by the feedstock supply analysis and ultimately reach the n^{th}-plant scenario described by the SOT analysis.

BIOMASS SUPPLY CHAIN RISK STANDARDS

Idaho National Laboratory

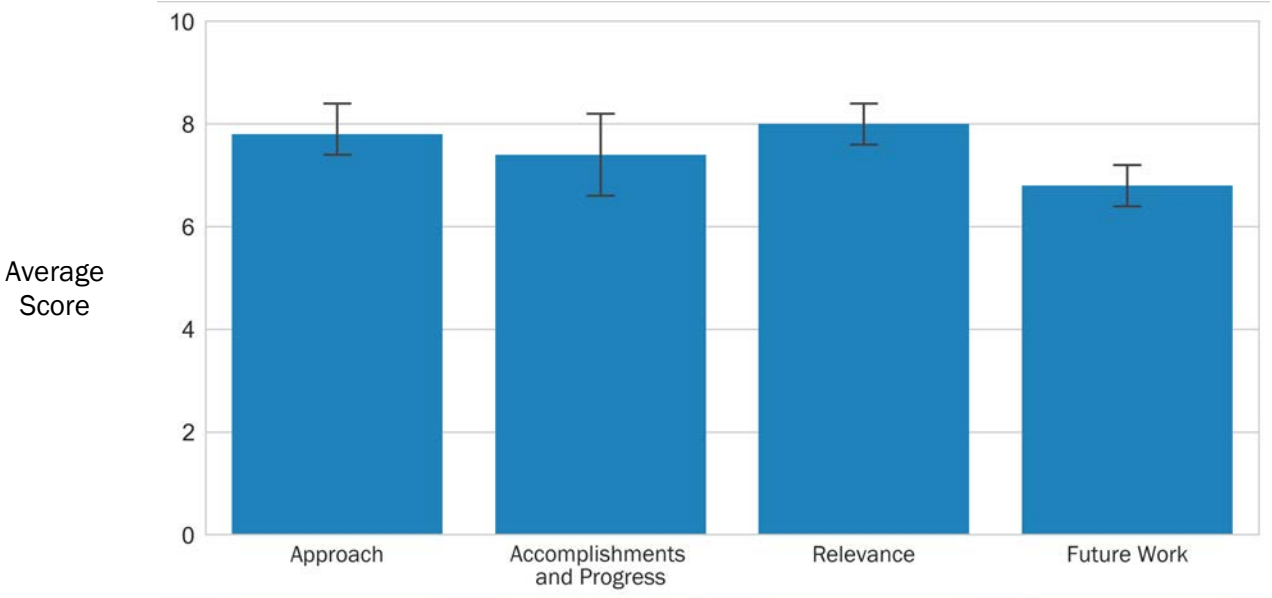
PROJECT DESCRIPTION

WBS:	1.2.2.2
CID:	NL0019449
Principal Investigator:	Dr. Shyam Nair
Period of Performance:	10/1/2014–9/30/2021
Total DOE Funding:	$4,023,887
DOE Funding FY16:	$752,250
DOE Funding FY17:	$993,250
DOE Funding FY18:	$1,267,089
DOE Funding FY19:	$1,011,298
Project Status:	Ongoing

The Biomass Supply Chain Risk (BSCR) standards project was conceived to solve the problems of high costs of debt and slow takeoff of bioenergy projects in North America. Both issues are linked to poor understanding of the underlying supply chain risks, the inconsistent way the risks are evaluated by different stakeholders, and asymmetry of information on the risks. A three-phase approach was established to address the financial challenges of bioenergy projects. Phase I included the development of a BSCR standards framework database, housed at INL's Bioenergy Feedstock Library (BFL), to identify risk categories in the supply chain, various risk factors within each identified risk category, and various risk indicators within each identified risk factor. This is accomplished with inputs from a bioenergy industry stakeholders' group and an advisory board, together comprising more than 100 members, which were formed for this project. The current BSCR standards framework consists of six risk categories: supplier, competitor, supply chain, feedstock quality, feedstock scale-up, and internal organization. These risk categories represent more than 300 risk indicators categorized into the multiple risk factors identified for each risk category. The main focus in Phase II will be on developing a risk scoring and rating methodology that will be implemented using the database to allow consistent estimation of biomass supply chain risks for a bioenergy project as well as to demonstrate real-life reduction of the cost of debt coupled with a consistent understanding of risk,

Weighted Project Score: 7.5

Weighting for Ongoing Projects: Approach-25%; Accomplishments and Progress-25%; Relevance-25%; Future Work-25%



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regardless of who conducts the assessment. In Phase III, the BSCR standards database, risk scoring, and rating methodologies will be verified across multiple bioenergy projects, and further efforts will be directed toward establishing an independent, industry-led standardization agency, a certification agency, and accreditation of the standards by ANSI.

Throughout all phases, a goal of this project is to provide state-of-the-science guidance for mitigating or assessing each risk indicator through identified resources, data, or knowledge built from existing data. The BFL houses not only the BSCR standards framework database but also a large amount of data on biomass and feedstocks across the United States, including analytic and metadata on more than 70,000 samples. For this project, publicly available BFL data will be formed into data sets, reports, and other tools to provide guidance on understanding and mitigating risk for relevant risk indicators. In addition, efforts are focused on creating a relevant data set and building a knowledge base for relationships between biomass variability in chemical characteristics and agronomic and environmental factors using historic data collected through the Regional Feedstock Partnership.

Using this three-phase approach, this project aims to demonstrate the utility of the BSCR to (1) more accurately quantify biomass feedstock supply chain risk and (2) verify the degree to which this standardized approach can decrease the debt costs of bioenergy projects based on real before/after investment data from actual bioenergy projects that require financing. The application of the developed potential BSCR standards and risk scoring and rating methodologies will be used with a case study to demonstrate a reduction in the project risk score of ≥ 50%.

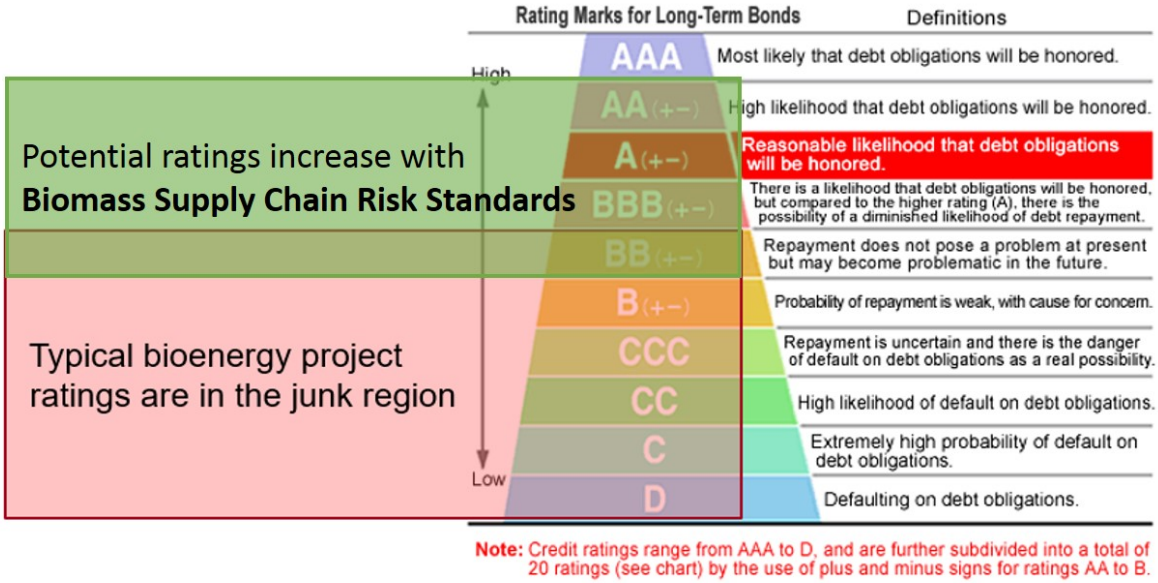


Photo courtesy of Idaho National Laboratory

OVERALL IMPRESSIONS

- This is interesting on a conceptual basis. Normally, one is reviewing the technical merits of a project that will hopefully solve a technical problem that is holding the biomass energy industry back. This is usually with a new conversion technology or some type of processing issue. This is extremely important work, however, because supply chain risk is one that the industry has never addressed in this manner. The rating agencies, i.e., Standard & Poor's, have never been able to assign ratings that take projects that are using conventional technologies or not out of junk financing status, which takes many projects out of

play because of the high borrowing cost. A successful outcome with this project will ensure the building of many projects.

- This project is a great effort in the direct response to feedback from earlier peer reviews. The TEA modeling (from other presentations) showed interest rates as the top cost sensitivity in the current n^{th}-plant models; thus, the importance of success in this project should be a high focus for BETO (or else we will need to rely on the USDA to provide financing for some time).

- The approach and progress both seem sound. The reviewer understands there to be very good industry involvement but suggests vetting the list once more to ensure that the actual end user/stakeholders will endorse and use the rating as soon as the work is done.

- Often the result of looking deeper into factors and applying variation factors to n^{th}-plant models is understanding that there is/are more risk(s) than originally perceived; thus, finalization of a feedstock supply risk reduction should be executed in tandem with variation control activities in other areas identified by the TEA team and presented together to avoid a swing in risk perception by investors.

- The need to better understand risk has been a major problem for research funded by DOE on all aspects of bioenergy development and demonstration since day one of DOE involvement (40 years ago). The creation of usable risk assessment tools could be a major assist to getting successful demonstration projects online and supporting the advancement of commercial enterprises. The extensive involvement of stakeholders in developing this risk evaluation tool is expected to contribute greatly to its usefulness. The need to balance detail and complexity with conciseness and ease of use will be ongoing. An aggressive effort to communicate the availability of this tool to a large array of potential users needs to be included in future plans.

- A supply chain risk tool can highlight areas that might otherwise be overlooked.

- Modeling feedstock supply risks will help credit sources understand aspects of the bioeconomy that they understand poorly now. This will help reduce capital costs if done accurately. Verifying the model developed here will be difficult because of the limited number of real case studies that exist.

RECIPIENT RESPONSE TO REVIEWER COMMENTS

- The reviewer's comment that "a successful outcome with this project will ensure the building of many projects," is encouraging and confirms our belief.

- The project has vetted the FY 2018 BSCR standards with members of the advisory board and key industry stakeholders. This has resulted in a revision of the standards with primary focus on removing redundancies, consolidating risk indicators, and adding guidance to risk scoring to enable the actual end user/stakeholders to use the rating system effectively. The revised BSCR standards and the risk scoring and rating methodology with example application will be available for review at the end of FY 2019. The BSCR standards team is working in tandem with other TEA teams and other researchers at the national laboratories to ensure that results from this research are considered in the guidance for mitigating risks as well as for scoring and rating the risks. The BSCR standards database is designed to accept and review comments, store them in perpetuity, and accept changes to guidance for risk mitigation, scoring, and rating by team members in response to review comments or new research in the future directly from the advisory board and industry stakeholders' group. Additionally, the BSCR standards database is currently available online through the BFL (https://bioenergylibrary.inl.gov/Home/Home.aspx) and will made publicly available when the standards are finalized.

- The project recognizes the importance of disseminating the information on the risk scoring and rating tool to the stakeholders, and it has therefore submitted a separate proposal to BETO for technical

commercialization funding with matching interest from Canada with the sole purpose of accelerating the design and implementation of an outreach and communications plan. A key part of the effort is to get the BSCR standards accepted and accredited by Canadian and U.S. standards programs, such as the Standards Council of Canada and ANSI. Additionally, the BSCR standards database is currently hosted on the BFL (https://bioenergylibrary.inl.gov/Home/Home.aspx) and will made publicly available when the standards are finalized.

- This project has focused on gathering industry input from multiple facets of the supply chain to identify all the risk indicators that should be considered in the framework. This approach was intended to capture a large breath of risk and prevent "overlooking" aspects of risk that should be considered.
- The project understands the challenges posed in developing realistic case studies for the verification of the risk scoring and rating methodology. Ecostrat is a subcontractor for the BSCR standards project and a key member of the team with considerable experience in the biomass supply business. With the contribution from Ecostrat and other key stakeholders, we believe that we can design realistic case studies well in advance of the FY 2020 go-no-go decision on the project. Note that the case studies used throughout the project are intended to be reviewed and approved by the advisory board.

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

FDC Enterprises

PROJECT DESCRIPTION

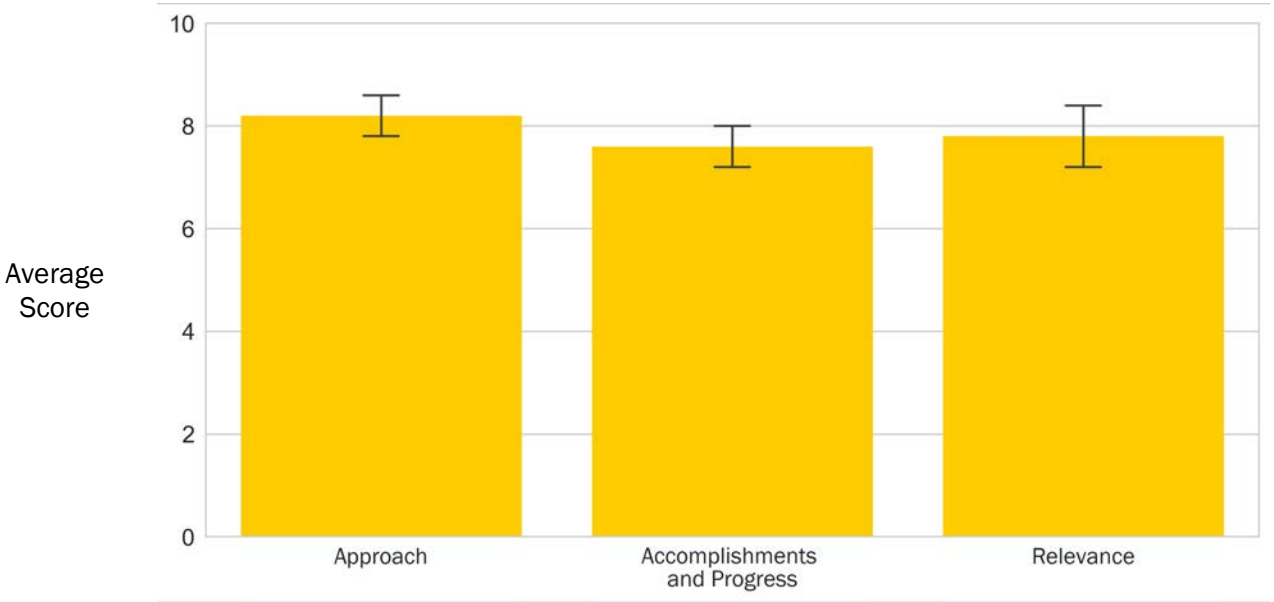
WBS:	1.2.3.106
CID:	EE0006300
Principal Investigator:	Mr. Kevin Comer
Period of Performance:	9/30/2013–3/31/2018
Total DOE Funding:	$5,400,000
Project Status:	Sunsetting

This project demonstrated 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 addressed several key technical barriers identified by the BETO biomass feedstock supply platform. This project built on the earlier supply chain innovations of project team members to reduce feedstock costs. This work highlighted key gaps throughout the supply chain where biomass harvesting and preprocessing costs could be further decreased while maintaining the end user's feedstock quality specifications.

This effort included designing and deploying new systems associated with end-use processing (new milling equipment, advanced bale handling, NIR monitoring and sampling, etc.), further refinement of feedstock production equipment developed and demonstrated under prior efforts and testing by this and other project teams, and demonstration of new feedstock harvest and logistics equipment. Importantly, this included the development of equipment and processes to provide biorefiners and harvesters the flexibility to produce and use round and/or square bales more efficiently and cost-effectively than is possible using today's off-the-shelf conventional equipment. The project team designed, fabricated, and tested several new equipment innovations, conducted commercial-scale biomass harvest demonstrations, developed, and tested new methods for analyzing biomass feedstocks with NIR methods both in the field and in a process line, and addressed soil

Weighted Project Score: 7.8

Weighting for Sunsetting Projects: Approach-25%; Accomplishments and Progress-50%; Relevance-25%



I One standard deviation of reviewers' scores

sustainability issues. Biomass preprocessing testing was also performed at pilot and commercial scales. The testing revealed new results that could better inform future equipment and system designs for preprocessing herbaceous biomass in a manner required to meet biorefinery specifications.

Photo courtesy of FDC Enterprises

OVERALL IMPRESSIONS

- Great progress was made here developing prototype equipment for efficient bale-handling systems in the field, in transportation, and at the refinery. Manufacturers were engaged throughout the process, and systems were adequately demonstrated.

- This is a big project with a lot of moving parts (literally) that was able to develop and demonstrate several different front-end equipment systems. The project took considered needs along the entire system, including labor, soil health, and existing industry. The project developed several working systems, including one that has already been scaled up at POET-DSM Advanced Biofuels. The presenter did a good job of illustrating the design-build-test-learn (DBTL) cycles used to succeed.

- This project has a full complement of work in terms of feedstock supply and logistics from the in-field crop to the reactor throat. NIR analysis results, not yet available, will provide more information on the feedstock characteristics and potential end uses.

- This is a good project that achieved favorable results and will help BETO reach its goals in the MYP of providing terrestrial feedstock in the form of corn stover to a reactor at $84/dry ton. That said, I believe that the results would be even better if these were compared to other similar operations, and cost comparisons were made. I think the project slips somewhat into a one-size-fits-all approach. For example, if you use a single-pass machine (combined with a baler attached) or a wind-rowing variable-rate corn head, you cannot separate the corn harvest from the stover harvest even though the stover might not be ripe for harvest simultaneously with the grain.
- This is an extremely comprehensive project aimed at increasing the probability of making the feedstock supply chains of corn stover and some herbaceous crops economically viable with boots-on-the-ground work. Much was accomplished in the 5-year time frame of the project. The project is a great example of what can be accomplished by a team of private-sector stakeholders working in collaboration with researchers and project developers.

RECIPIENT RESPONSE TO REVIEWER COMMENTS

The recipient choose not to respond to the reviewers' overall impressions of their project.

NEXT-GENERATION LOGISTICS SYSTEMS FOR DELIVERING OPTIMAL BIOMASS FEEDSTOCKS TO BIOREFINING INDUSTRIES IN THE SOUTHEASTERN UNITED STATES

University of Tennessee

PROJECT DESCRIPTION

WBS:	1.2.3.107
CID:	EE0006639
Principal Investigator:	Dr. Tim Rials
Period of Performance:	2/1/2016–1/31/2020
Total DOE Funding:	$3,726,000
Project Status:	Ongoing

The diverse portfolio of biomass sources that is available in the Southeastern United States, including a significant supply of pine "residue," represents a valuable strategic position for the region. Through blends formulated based on critical properties, this project will take full advantage of the range in biomass properties afforded by the portfolio to produce a consistent, high-performance feedstock for the industry while reducing cost. Key developments being targeted to enable this potential include whole-tree transport to a state-of-the-art merchandising depot that will further access biomass from ongoing forest industry operations. The approach will more effectively use the tree and distribute cost while minimizing in-woods contamination of the woody biomass component. To implement this vision, information on the chemical composition and changes that are induced during multiple preprocessing steps (size reduction, moisture removal, densification, etc.) is needed. New NIR sensor technology will be developed for online monitoring of important biomass properties. The data will be incorporated into a statistical process control platform to improve process efficiency and meet required specifications. Advanced process models are being developed to inform the TEA and LCA of the program's impact. The new system will ultimately reduce operational risks from supply chain disruptions and allow for the operation of larger biorefineries.

Weighted Project Score: 7.0

Weighting for Ongoing Projects: Approach-25%; Accomplishments and Progress-25%; Relevance-25%; Future Work-25%

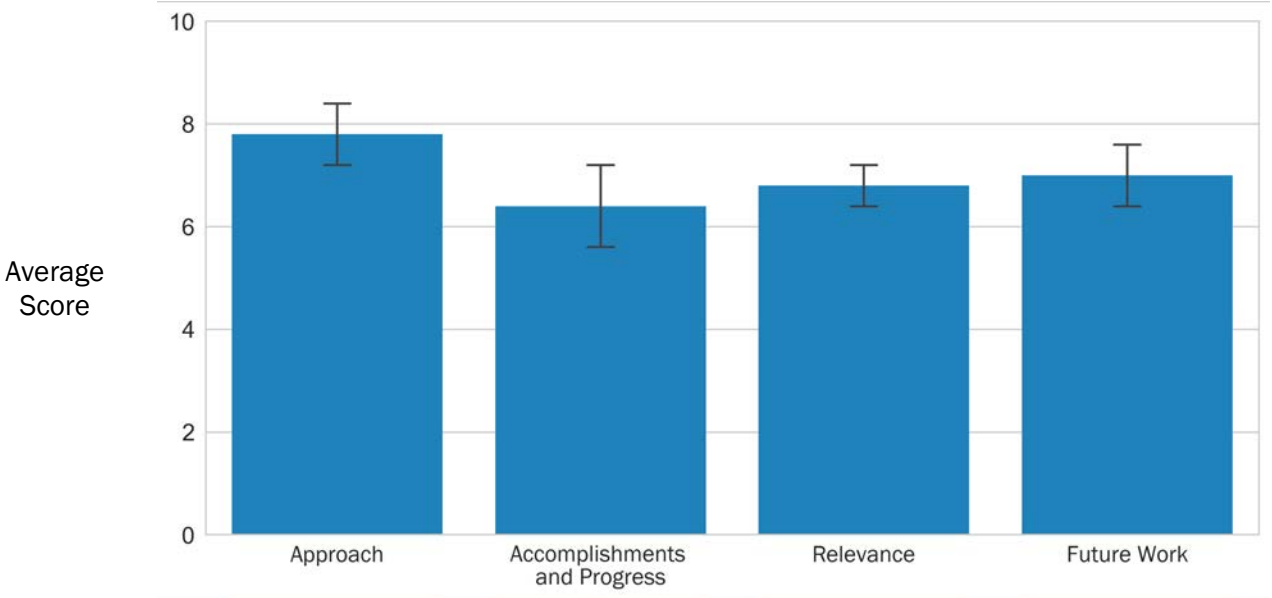


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Photo courtesy of University of Tennessee

OVERALL IMPRESSIONS

- This project seeks to tap the woody and grassland resources of the Southeast in creative and synergistic ways. The novel idea here is to combine raw feedstocks in ways to meet quantity and quality requirements of a variety of bioproduct conversion processes. It remains to be seen how widely this technique will be adopted by a nascent bioeconomy, but the idea is intriguing.

- This is a key project in support of the SOT effort to reduce the cost of feedstock (depot concept).

- Despite some setbacks with regard to losing their site partner, the project has worked hard to prove out the concept and identify a new partner. The project will run over on time but not cost.

- The project contained all the needed components for feedstock supply chain system evaluation in the Southeast and pulled together an excellent team of collaborators. The evaluation of feedstock supply scenarios using depots and pelleting to assist in meeting storage and quality standards for biomass feedstock supplies is conceptually a valuable contribution to the BETO portfolio. There are hints that much good work has been accomplished; however, the presentation did not contain enough information to properly assess the progress or the likelihood of the project goals being accomplished.

- The project addressed a variety of identified FSL barriers. Methods explored for increasing pine biomass from the stump to the mill do not seem to require a large additional capital investment by traditional logging firms.
- I would have welcomed some detail about the relevance of past work and its relationship to this work in the presentation. The economics of operating an advanced merchandising depot were discussed, but I could not determine if the costs of getting raw biomass supplies to the depot was part of this work. If it was, it was not clear; and if it was not, I would have expected it to be included. Their reliance on switchgrass in this work and system makes for a better system, especially at large scales, but the barrier of access to potential large supplies necessary to operate this type of depot could seriously impair the development of this type of system.

RECIPIENT RESPONSE TO REVIEWER COMMENTS

The recipient choose not to respond to the reviewers' overall impressions of their project.

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

The Research Foundation of The State University of New York College of Environmental Science and Forestry

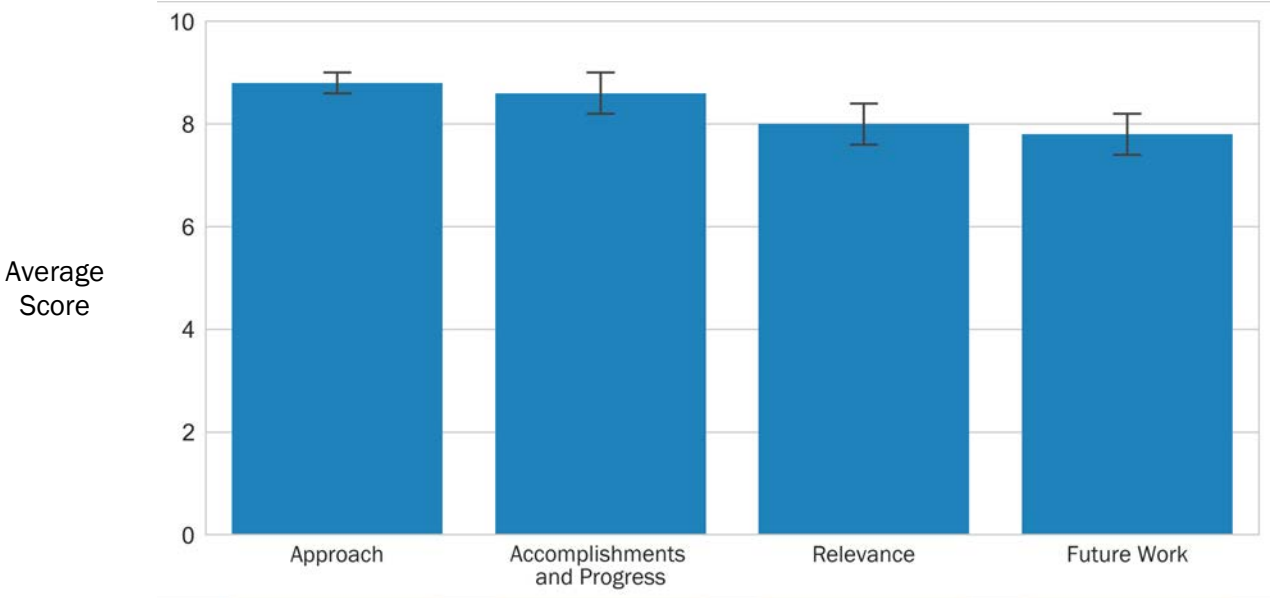
PROJECT DESCRIPTION

WBS:	1.2.3.108
CID:	EE0006638
Principal Investigator:	Dr. Tim Volk
Period of Performance:	4/1/2016–6/30/2019
Total DOE Funding:	$2,320,182
Project Status:	Ongoing

The goal of this project is to reduce the delivered cost of hybrid poplar in the Pacific Northwest and willow woody crops in the Northeast to $84/dry ton ($92 dry Mg) 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. Tasks are integrated using an iterative process involving data collection from commercial harvests, provision of these data to modeling teams, and addressing data goals or application of suggested improvements in subsequent harvests. During this project, almost 800 wagon loads of willow and poplar chips were harvested and monitored in a wide range of field and crop conditions as part of Task 1 to assess the effect on machine performance and fill specific data gaps identified by the modeling task group. Studies of woody crop chips stored over time in Task 2 has provided valuable insights on how season, preprocessing, pile construction, and protection of piles affect dry matter loss, moisture, and other quality attributes. Some results raise questions about how quality is tied to biomass value and how growers are compensated for the material that is delivered. Field trials suggest that bulk density of willow chips is more variable in collection vehicles than has reported in the literature using standard methods on small containers. This has implications for cost and environmental

Weighted Project Score: 8.3

Weighting for Ongoing Projects: Approach-25%; Accomplishments and Progress-25%; Relevance-25%; Future Work-25%



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modeling of these systems. Task 3 process demonstration studies at INL suggest that high moisture densification and coarse grinding of willow and poplar reduce energy consumption by 20%–40% for densification. In addition, partners have identified the best choice of time and temperature to optimize the hot water extraction preprocessing technology and provided the necessary model inputs so hot water extraction can be included in the INL Biomass Logistics Model. In Task 4, wet chemistry data from 77 samples was used to develop NIR models, and spectra for more than 1,500 willow and poplar samples were collected. In Task 5, each of the three modeling efforts was impactful: Integrated Biomass Supply Analysis and Logistics modeling has shown that costs range from $26 to $45 per Mg and are lowest when silage trucks are collection vehicles. The West Virginia University model completed an optimized siting model identifying 15 potential locations for biorefineries in the northeastern United States and delivered biomass cost ranged from $68 to $87 dry Mg based on site and social factors.

OVERALL IMPRESSIONS

- This project addressed the highest cost aspects of SRWC production (harvesting and handling) and demonstrated ways to improve the state of the art and reduce costs. Progress was also made in exploring one option for feedstock upgrading using hot water extraction technology.

- This is a good project that created a lot of frontend data and laid groundwork for logistics needs for short-cycle woody biomass as well as compositional effects of storage. Effort changed the minds of several existing biomass operations with regard to taking willow into their operations, to the point where a competitor in Canada appeared. Finalizing the project will be important; it seems like there is a lot to do to finish runs at the Biomass Feedstock Process Development Unit.

- This project has a great team of collaborators with the correct expertise to develop information needed by BETO to meet national goals of developing sustainable technologies to provide a secure, reliable, and affordable woody feedstock supply for the U.S. bioenergy industry. This project has gone a long way toward catching up with the types of handling, storage, and processing information already known about corn stover and switchgrass so that SRWC have every possibility of being a feasible and desirable feedstock in regions where willows and poplars make the most sense as dedicated crops for bioenergy and bioproducts. The involvement of the private sector and state agencies in the project should accelerate the possibility that commercial entities will use the information. This integrated systems project appears to be progressing very well with all tasks; however, much work remains to pull all the information together for final reports and dissemination to stakeholders.

- This project provided a full complement of tasks for understanding the complexities of harvesting coppiced woody biomass.

- The project performers created a presentation that is clear, concise, and well executed. When completed, the project can have a solid effect on the bio-based economy by promoting the use of SRWC as a viable, high-quality, and sustainable source of feedstock. The only real weakness I see in the project and presentation, however, is that there was no attention in the future work on how to promote the use of these feedstocks and get our agriculture community to grow them.

RECIPIENT RESPONSE TO REVIEWER COMMENTS

The recipient choose not to respond to the reviewers' overall impressions of their project.

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

Humboldt State University

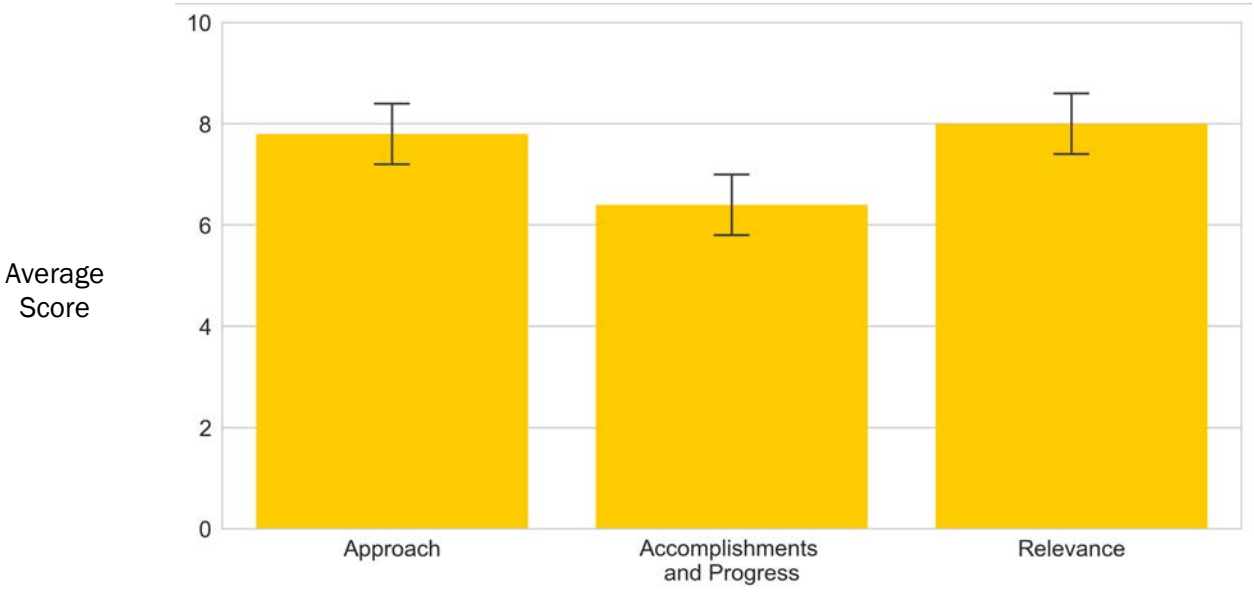
PROJECT DESCRIPTION

WBS:	3.4.1.4
CID:	EE0006297
Principal Investigator:	Dr. Han-Sup Han
Period of Performance:	9/30/2013–12/31/2017
Total DOE Funding:	$5,881,974
Project Status:	Sunsetting

Overcoming the barriers to using low-value forest residues that are generated from forest management activities can be accomplished by employing biomass conversion technologies. At present, the greatest obstacle to increasing the use of these materials is the high transportation cost. Biomass conversion technologies can convert comminuted forest residues into biochar, torrefied pellets, and briquettes, thereby improving their market desirability, increasing their value, and increasing transportation efficiencies. The Waste to Wisdom project was part of the Biomass Research and Development Initiative, and funded by DOE (DE-EE0006297) at $5.8 MM. Our interdisciplinary research team—comprising academics, business professionals, and land managers—worked together for approximately four years (September 2013 to December 2017) to (1) develop system logistics that improve the economics, accessibility, and production of high-quality feedstock; (2) evaluate and scale up stand-alone biomass conversion technologies that are operated at or near the forest for their commercialization; and (3) perform economic analyses and life cycle emissions analysis to enhance the sustainability of biomass use through improved knowledge of socioeconomic and environmental benefits. The Waste to Wisdom project found that the commercialization of biomass conversion technologies 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 could create employment in the forest and energy sectors, support economic development in rural areas, and effectively reduce our nation's dependence on fossil

Weighted Project Score: 7.2

Weighting for Sunsetting Projects: Approach-25%; Accomplishments and Progress-50%; Relevance-25%



I One standard deviation of reviewers' scores

fuels by incorporating renewable fuels into current bioenergy and coal-fired energy facilities. We encourage those who are interested to visit the project web site (http://wastetowisdom.com/) to learn more about the team's research on feedstock development, biomass conversion technologies, and the financial and environmental benefits of using forest residues for the production of bioenergy and bio-based products.

OVERALL IMPRESSIONS

- This project explored ways to reduce the environmental and carbon impacts of current logging slash disposal practices in the Northwest while creating value-added products from this otherwise unavailable material. Unfortunately, the economics of this practice are still far from practical without allowing for the value of certain intangible benefits to the environment (e.g., air quality improvements, fire suppression).

- This is a good project result with no scaling factor to commercial scale as well as some reasonable window for commercial viability. The concept solves a real technical problem on how to handle forest thinnings in a practical way; however, the project did not seem to have a well laid out commercialization plan, and thus focus on the business case needs to be executed to validate the financial assumptions and define a commercialization partner/municipality.

- This project explored a wide variety of topics that add value to biomass prior to delivery to an end-user facility.

- Forest residue has long been looked at for use as a fuel or feedstock and is a significant resource according to the *2016 Billion-Ton Report*; however, as most know, it is challenging from an economic standpoint to create a profitable enterprise. This project addresses that by bringing three different conversion technologies to the forest and then creating useful and profitable products at demonstration scale. A good marketing plan could help create some positive commercial activity around this concept and help elevate the work BETO is doing.

- The project achieved its stated goals of producing products from forest residues, developing three feedstock processing systems that could be performed near forestry operations sites, and evaluating the feasibility of the feedstock products for economic viability in bioenergy and bioproduct markets. An outcome of the project was the development of a baler for forest residues that might be a useful first step in other systems using forest residues. Demonstrations of the three process systems provided the information needed to evaluate costs and identify efficiency factors. The reported total system costs of producing biochar, biomass briquettes, and torrefied briquettes were too high to be useful in supporting the achievement of the bioenergy cost goals of BETO, though information was gained on improving efficiencies of the systems. The biochar product was the most interesting product because it might have a bioproduct market in some locations, and it has strong environmental benefits (soil remediation and carbon sequestration in the soil).

RECIPIENT RESPONSE TO REVIEWER COMMENTS

The recipient choose not to respond to the reviewers' overall impressions of their project.

CEMAC: EVALUATION OF AGRICULTURAL EQUIPMENT MANUFACTURING FOR A BIO-BASED ECONOMY: NREL

National Renewable Energy Laboratory

PROJECT DESCRIPTION

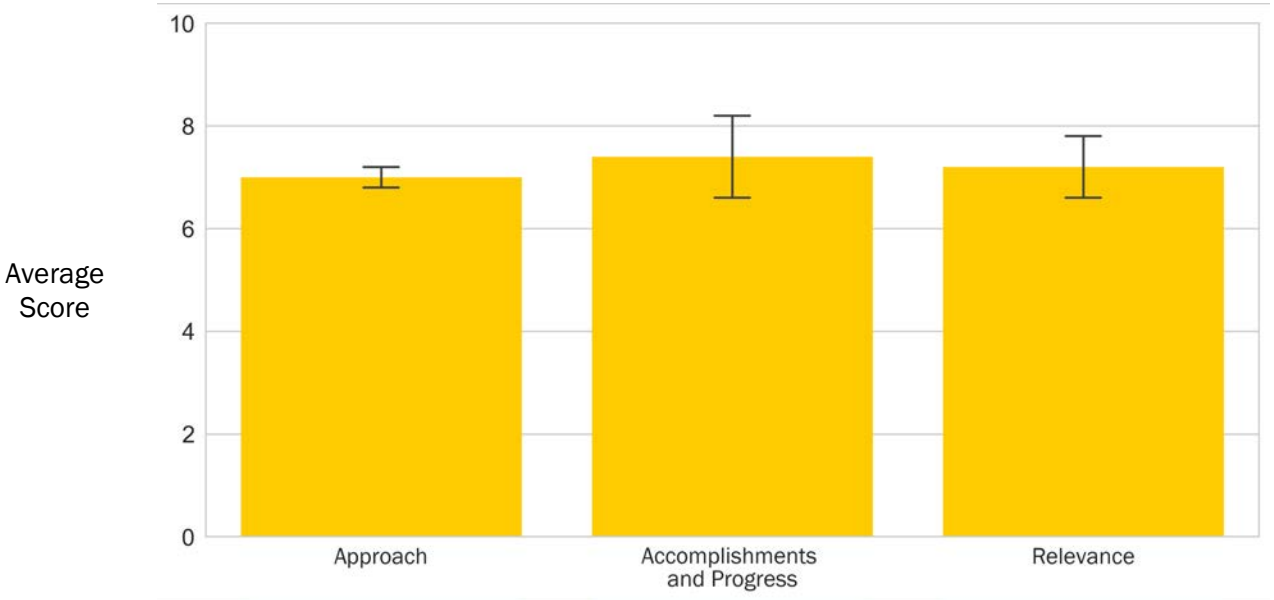
This study analyzes agricultural and preprocessing equipment and manufacturing requirements to support the mobilization of the projections in the DOE *2016 Billion-Ton Report* using the conventional supply chain logistics. The report discusses the required number of agricultural machines and their market values, the drivers and barriers of the transition in agricultural equipment, the potential economic impacts to the United States associated with this transition, and the factors that impact the transition in agricultural machinery to support the growth of a large-scale biofuel and bioproduct industries.

WBS:	6.3.0.8
CID:	NL0030036
Principal Investigator:	Dr. Chad Augustine
Period of Performance:	10/1/2016–3/31/2018
Total DOE Funding:	$93,900
DOE Funding FY16:	$50,000
DOE Funding FY17:	$6,000
DOE Funding FY18:	$37,900
DOE Funding FY19:	$0
Project Status:	Sunsetting

Five major biomass resources are selected for the analysis of feedstock equipment and manufacturing requirements to support the mobilization of commercial quantities of biomass resources using the conventional supply chains: corn stover, switchgrass, miscanthus, coppice woody crops, and non-coppice woody crops. Based on the *2016 Billion-Ton Report*, 304 million–652 million tons per year of these biomass resources are available from agricultural lands in the United States. Using the Oak Ridge National Laboratory Supply Characterization Model, the selected biomass resources could support an estimated 240–358 potential biorefineries that convert 230 million–340 million tons of selected biomass resources to biofuels annually. In the short term, it is estimated that approximately 280,000 pieces of

Weighted Project Score: 7.2

Weighting for Sunsetting Projects: Approach-25%; Accomplishments and Progress-50%; Relevance-25%



equipment with a market value of $36 billion would be required to harvest and deliver the biomass to the biorefineries. In the long term, this number is estimated to be approximately 380,000 pieces with a market value of more than $47 billion. Analysis of the current U.S. agricultural equipment manufacturing industry suggests that approximately 70%–80% of total U.S. agricultural equipment demand is supplied from domestic manufacturers. Assuming that U.S. agricultural equipment manufacturing under the *2016 Billion-Ton Report* scenarios are similar, the sum of direct long-term employment impacts from U.S. agricultural equipment manufacturing is more than 56,000 full-time equivalent job years, and the sum of the total long-term impacts is more than 340,000 full-time equivalent job years. The domestic manufacture of the required equipment would result in almost $11 billion in direct value added (contribution to the gross domestic product [GDP]) and nearly $40 billion in total value added (contribution to the gross domestic product) during the long term. These are upper-end estimates because they assume that 75% of all agricultural equipment is manufactured domestically and that all required agricultural equipment is newly manufactured.

The study identifies and studies several recent transitions that took place in the agricultural farm machinery and the preprocessing equipment. These transitions are evaluated to outline the drivers and barriers of these new pieces of equipment. These transitions also provide insights into the transition needed from existing biomass supply chain systems to advanced supply chains. The project team completed this task by contacting and interviewing the companies behind the development of these pieces of equipment. Farm machinery supply chains need strong signals from biomass producers, biomass logistics companies, and biomass end users to tackle the barriers for the adoption of new technologies.

OVERALL IMPRESSIONS

- Understanding the harvesting equipment needs to satisfy a hopeful large buildout of biomass production is important to educating the suppliers as well as the users. The project used several very key assumptions to scope the work that, once built out, paints a relatively clear picture for the future.

- The SOT moves toward blended feedstocks, pelleting, ownership, and other cost drivers, however, will likely significantly change the conclusions of this study, and as a result should also be modeled to fully build out the equipment supply picture.

- This was a straightforward, well-focused project addressing relevant and important questions about potential equipment manufacturing requirements as well as potential impacts on jobs and GDP. The approach was excellent in terms of using expertise from the DOE laboratories involved in considering feedstock supply issues and in communicating discussions of the issues together with industry stakeholders. The objectives of the project seemed to be totally addressed, the results were presented very clearly, and a well thought out interpretation of the results was included in the presentation. This analysis is a good complement to the Feedstock Supply Chain Analysis and the Supply Scenario Analysis projects also funded by BETO. As with all these modeling efforts, the results are useful for planning and communicating what a future situation might look like but are not predictive with the many changes in supply chain details that will inevitably occur.

- This project provides insight into how the feedstock supply chain could positively impact equipment manufacturing and jobs.

- I think interfacing more with industry would have helped clarify the size of this potential requirement as it relates to the existing agricultural equipment market. For example, although the tractor market in North America is some 280,000 units, only 10% of these are in the high-horsepower category, the size needed to operate the various implements in either the baling or chopping scenario. Therefore, in the baling scenario, estimates are for approximately 50,000 units in the short-term, early-development phase, equal to +/- 200% of today's production. This could also be said of the balers and forage choppers. Depending on the ramp-up of the industry, this could put tremendous pressure on the industry in terms of

manufacturing capabilities on all fronts: manufacturing facilities, engineers, steel fabricators, labor, dealers, and parts manufacturing, to name a few.

- This project made a first attempt to estimate the machinery requirements for bioenergy feedstock harvesting and handling in agricultural systems across the United States and to estimate the economic impact this might have on the country. Assumptions made to model this impact are enumerated, so adjustments can be made if different assumptions are deemed to make more sense.

RECIPIENT RESPONSE TO REVIEWER COMMENTS

The recipient choose not to respond to the reviewers' overall impressions of their project.