ANALYSIS AND SUSTAINABILITY

TECHNOLOGY AREA

CONTENTS

INTRODUCTION

Six external experts from industry, academia, and other government agencies reviewed 27 projects in the Analysis and Sustainability (A&S) session.

This review addressed a total U.S. Department of Energy (DOE) investment value of approximately $48 million, which represents approximately 6.8% of the Bioenergy Technologies Office (BETO or the Office) portfolio reviewed during the 2017 Project Peer Review. During the Project Peer Review meeting, the principal investigator (PI) for each project was given between 15 and 30 minutes (depending primarily on the project's funding level and relative importance to achieving BETO goals) to deliver a presentation and respond to questions from the Review Panel.

The Review Panel evaluated and scored projects based on 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 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 A&S Program Area, full scoring results and analysis, the Review Panel's summary report, and BETO's programmatic response are also included in this section.

BETO designated Kristen Johnson and Alicia Lindauer as the A&S Technology Area Review Leads. In this capacity, Ms. Johnson and Ms. Lindauer were responsible for all aspects of review planning and implementation.

A&S OVERVIEW

BETO is committed to growing a bioenergy industry that enhances energy security, promotes environmental benefits, and creates economic opportunities. To that end, the A&S Technology Area addresses the challeng¬es related to sustainable bioenergy production and use by supporting analysis, data collection, modeling, and applied research and development (R&D) projects. This technology area works collaboratively with industry, academia, national laboratories, nongovernmental organizations, other agencies, and international partners.

This technology area plays a crosscutting role within and outside the Office. It contributes to portfolio planning and works with other BETO technol¬ogy areas to develop and advance technology-specific sustainability and analysis objectives. Externally, it contributes scientific knowledge and tools related to understanding and enhancing the economic, environmental, and social effects of advanced bioenergy.

A&S Support of Office Strategic Goals

The Sustainability strategic goal is to understand and promote the positive environmental, economic, and social effects and reduce the potential negative impacts of bioenergy production activities.

The Strategic Analysis strategic goal is to provide context and justification for decisions at all levels by establishing the basis of quantitative metrics, tracking progress toward goals, and informing portfolio planning and management.

A&S Support of Office Performance Goals

Sustainability: Sustainability activities support the Office's strategic goals by providing science-based quantification of the sustainability of advanced bioenergy and promoting improved environmental performance and social benefits of bioenergy relative to conventional or business-as-usual energy systems. The Sustainability portfolio interfaces with and impacts all elements of the biomass-to-bioenergy supply chain and each stage

of technology development. Considering sustainability early in technology development—rather than after systems are finalized and replicated—enhances the future economic and technical viability of those technologies. Sustainability activities closely align with the feedstock and technology pathways pursued under the Office's R&D and market transformation areas.

Strategic Analysis: Strategic Analysis activities are designed to support Office decision-making processes and advance scientific understanding in crosscutting areas. Supported activities validate decisions, ensure objective inputs, and respond to external recommendations. Other projects in the Strategic Analysis portfolio strive to advance the state of the science within areas such as life-cycle analysis (LCA), land-use change (LUC) modeling, and bioenergy impact analysis. BETO provides ongoing analysis and policy-relevant support to other U.S. government agencies and legislative bodies. Emerging issues, interests, and trends raise new questions from a wide variety of stakeholders including DOE management, members of Congress, other federal agencies, and state governments. Scholarly articles, popular media, and other broader forums are additional sources of questions for analysis.

A&S Approach for Overcoming Challenges

BETO has identified the following key challenges for achieving the goals of the A&S Technology Area:

Sustainability Challenges and Barriers
• Sustainability data across the bioenergy supply chain
• Consistent and science-based message on bioenergy sustainability
• Science-based methods and tools for evaluating and improving sustainability
• Capturing social and environmental benefits in bioenergy's value proposition
• Social acceptance and stakeholder engagement
• Land use and interactions with agricultural, forestry, and natural systems
• Best practices and case studies on sustainable bioenergy production
Strategic Analysis Challenges and Barriers
• Comparable, transparent, and reproducible analyses
• Analytical tools and capabilities for system-level analysis
• Data availability across the supply chain

The A&S Technology Area works to overcome these challenges by developing and disseminating knowledge, tools, and mechanisms for more-informed decision making and better resource management. Key partners include national laboratories—primarily Argonne National Laboratory (ANL), Idaho National Laboratory (INL), the National Renewable Energy Laboratory (NREL), Oak Ridge National Laboratory (ORNL), and Pacific Northwest National Laboratory (PNNL)—academia, nongovernmental organizations, industry, and international organizations. This technology area coordinates internally and externally, working closely with other BETO technology areas, DOE offices, and federal agencies, such as the U.S. Department of Agriculture (USDA), U.S. Environmental Protection Agency (EPA), U.S. Department of Defense, and U.S. Department of Transportation. Robust stakeholder engagement—through workshops, roundtables, and other means—helps advance crosscutting objectives.

The scope of A&S projects includes the following:

- **Resource and technical assessments** that provide the analytical basis for program planning and evaluation of progress
- **Market and impact analyses** that focus on understanding the impact of R&D and bioenergy industry development
- **Advancement of scientific methods** and models for measuring and understanding bioenergy sustainability across the full supply chain
- **Dissemination of practical tools** for analyses, decision making, and technology development that enhance sustainable bioenergy outcomes
- **Data compilation** to develop and maintain tools to assist in collecting, compiling, and analyzing data
- **Quantification of improved environmental performance and social benefits** of bioenergy relative to conventional or business-as-usual energy systems
- **Development of landscape design approaches** that increase bioenergy production while maintaining or enhancing ecosystem, economic, and social benefits

These activities contribute to a better understanding of environmental, economic, and social aspects of bioenergy. A key priority is to analyze trends and trade-offs across multiple supply chain components and sustainability categories.

Outcomes from A&S Technology Area activities are disseminated through publications, web tools such as the Bioenergy Knowledge Discovery Framework (KDF), interagency coordination, and domestic and international stakeholder interactions. They are also used by BETO to inform technology research and development to maximize beneficial outcomes.

For more information on the A&S Technology Area, please review the A&S chapters in BETO's 2016 *Multi-Year Program Plan*.[36]

A&S REVIEW PANEL

The following external experts served as reviewers for the A&S Technology Area during the 2017 Project Peer Review.

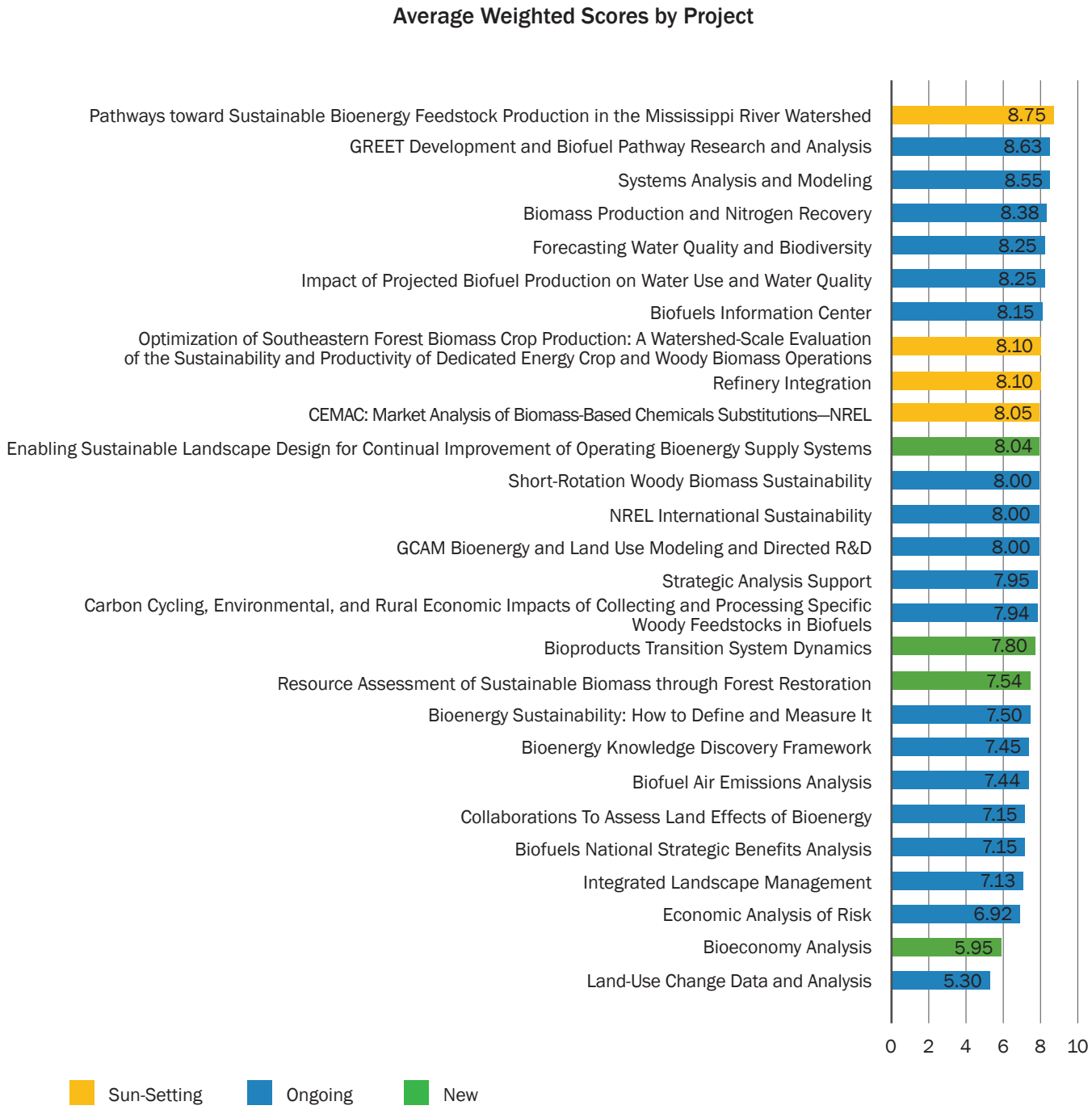
Name	Affiliation
Candace Wheeler*	General Motors (Retired)
David Simpson	EPA, Office of Policy
Christopher Galik	North Carolina State University
Troy Hawkins	Eastern Research Group Inc.
Ruben Lubowski	Environmental Defense Fund
Kate Behrman**	Colorado State University

* Lead Reviewer

** FSL reviewer borrowed for feedstock sustainability projects.

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

A&S SCORE RESULTS



A&S REVIEW PANEL SUMMARY REPORT

Prepared by the A&S Review Panel

Introduction

The A&S Program plays a key enabling role in the overall BETO portfolio. It is crosscutting and forms the foundation for other technology areas by focusing on the environmental, social, and economic impacts of the growing biofuels and bioproducts industries. The Review Panel reviewed a total of 28 projects over 3.5 days. The Panel would like to begin by thanking the PIs for their hard work, innovation, and presentations. The Panel was very impressed with the depth and breadth of the projects as well as the diversity and significance of the projects individually and as a whole.

The Panel found the project management to be very effective both at the program level and project levels. Given the diverse nature of the projects, this is not an easy task but one that was accomplished with great dedication and leadership. Great efforts toward collaborating, communicating, goal setting, meeting milestones, and validating the work were evident. The projects showed solid designs, methodologies, and stakeholder engagement. Of particular note was the outreach to stakeholders and industry which helped to ensure the projects were relevant and timely as well as demonstrated a clarity of goals and purpose.

In the following summary, the Review Panel addresses six key questions looking at the impact, innovative nature of the projects, as well as synergies between the projects in the portfolio. The Panel also addresses the current focus of the portfolio in an attempt to identify gaps or areas that should be deemphasized as well as how these projects translate into commercialization. Finally, the Panel offers recommendations for strengthening the portfolio in the near to medium term.

Impact

There is no doubt that the A&S portfolio is designed to have significant impact. The *2016 Billion-Ton Report: Advancing Domestic Resources for a Thriving Bioeconomy* (*BT16*) highlighted the depth and breadth of the A&S Program and provided an opportunity to use the tools and capabilities developed in this program on real world scenarios in a more integrated approach. *BT16* illustrated the importance of the sustainability issues in the bioeconomy and the critical nature of understanding the environmental, economic, and social impacts of the system. Understanding the impacts on greenhouse gas (GHG) emissions, water use, and LUCs as well as job creation, rural development, and energy security of significant bioenergy production as outlined in *BT16* would not have been possible without the tools and methodologies developed by this program.

Impact is the key strength of this program. It serves as the foundation and a partner for all of the other program areas. Its tools and methodologies are used across BETO to deliver the information and analysis critical to decision making and optimization both at a higher strategic level and at the fundamental pathway or project technology level. While the expertise and output from this group has been used over the years by researchers to determine the impacts of various technologies and in optimizing technologies around economics and environmental goals, in recent years, the emphasis and expertise has been expanded to look at the social aspects of the bioeconomy as well.

The Panel felt the A&S portfolio showed the right balance between redundancy and independence in work across projects. The Panel noted much better integration and collaboration within and between projects in the program. Researchers from numerous institutions collaborated on many of the projects bringing with them their unique expertise and collective wisdom. Some have criticized the A&S Program in the past for its extensive reliance on government national laboratory

employees with fewer projects awarded to university and industrial partners. However, this also illustrates this technology area's impact. Much of the work is outside the capability and expertise of private industry. Tool development requires a massive effort and is outside the scope and time constraints of industry. Therefore, programs such as this one are the only places where this type of fundamental, precompetitive work can be accomplished. The work being done in this program is significantly advancing the knowledge and capabilities in this area. The program has been able to develop a core group of highly skilled experts to do this work while still leveraging a variety of industry and external partners. These external partners, in turn, provide direction and ensure relevance to the projects.

Analytical methodologies and tools are critical to providing quantifiable results. The tools developed by the A&S program have been integral to providing an "apples-to-apples" comparison of technologies and their outcomes. Tools like the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model have been used by EPA and other agencies in enforcing regulations such as the Renewable Fuels Standard (RFS). A big push since the last review has been made to make more of these tools publicly available. Getting these tools into the hands of more researchers will increase the impact many fold.

While the bulk of the work in the A&S Program offers exceptional value, the Review Panel found several areas that stood out from the rest. One example of these is the LCA and techno-economic analysis (TEA) work done throughout the program. Models such as ANL's Impact of Projected Biofuels Production on Water Use and Water Quality and its GREET model are examples of this work. This work has long been a backbone of the program and continues to produce high-quality analysis used by industry and regulators. It was evident to the Review Panel that efforts have been made in the last two years to make sure the models are compatible allowing for the integration of the findings for a more robust analysis.

A second area of exceptional value is in Systems Analysis and Modeling. The systems work helps to provide a broader picture and understanding of the market implications and policy influences of various technology developments. This work helps to solidify and integrate much of the other work being done and serves as a critical tool in strategic decision making and direction.

Another area to receive high marks was the Clean Energy Manufacturing Analysis Center (CEMAC): Market Analysis of Biomass-Based Chemicals Substitutions. While a sun-setting project, the project aligns well with BETO's goals to develop a deeper understanding of bioproduct markets, economics, and sustainability and illustrates the ability to use the expertise developed in the program to address a specific issue. The study went beyond just techno-economic considerations to include market drivers and sustainability metrics in the evaluation. The findings confirm that biobased chemicals and bioproducts could serve as an enabler for the biofuels industry by helping to mature the biomass supply chain and provide initial wins for the bioeconomy.

Finally, the Review Panel would like to recognize the impact that good communications plays in the bioeconomy. Efforts through the Biofuels Information Center (BIC), as well as standard setting and international engagements, are instrumental in translating the good work done through the program into actionable intelligence and decision making. Strong research is only good if the information makes it into the hands of those who use it to make a difference in the world. We applaud the A&S Program's efforts to provide access to scientific-based information and engage in informing and influencing the ongoing bioeconomy debate.

Innovation

The Panel observed a maturing of the projects as well as the capabilities and expertise associated with these projects. The A&S Program has spent years developing and improving on the models in their tool kit. This work is coming to fruition. While there continues to be new

areas such as bioproducts that need to be added to the models, the models themselves are now being used to perform strategic analysis and impact decision making. This is a huge win for the program, but it also requires some change in direction as some of the work shifts from model development to utilization.

The core team of experts assembled by the A&S Program is optimally positioned to respond to changes in direction, new innovations, and short-term requests as well as long-term research needs. This was aptly demonstrated by the changes made in the portfolio since the last review. The A&S team was quick to respond to BETO's change in direction by looking at bioproducts and their impact in the bioeconomy as well as including social (e.g., job creation or rural development) and other sustainability indicators. The methodology and tools developed by the program are innovations in their own right. They are, however, being utilized to assess and compare new technologies to ensure these innovative processes are sustainable.

The Review Panel deeply appreciates the A&S Program's efforts to expand and include more qualitative and hard-to-measure aspects of sustainability including social aspects in its analysis. This is itself innovative and leading edge.

Synergies

The Review Panel observed a great deal of collaboration evident in the projects, much more than was present two years ago. There was significant data sharing and a high degree of interaction between laboratories and external partners. Principal researchers from multiple laboratories were co-investigators and contributors to the projects. A great deal of effort was made to make sure data created by one project could feed into or inform another. This level of synergy does not happen spontaneously but was obviously encouraged by BETO management.

It was particularly noteworthy to see examples of data generated in one project used by a second project. It was also gratifying to see the modeling work move toward common outputs that could be easily used by other systems. This type of interaction and effort aided in enabling the synergy of the projects and should continue to be encouraged moving forward.

One suggestion that was made by the Review Panel was to develop a road map of the various projects in an effort to see where each project lies and how they interact. The leadership informed the Review Panel that this effort was currently underway. We would encourage the leadership to complete this exercise as it helps not only in identifying synergies but also gaps in the portfolio.

Focus

In a program such as A&S, it is critical to understand the bigger picture not only to ensure collaboration and consistency across the projects but to identify gaps in the program. The A&S Program is by nature a complex, diverse set of issues, methodologies, and tools. It would be easy in this vast program area to lose focus. The A&S Program management has been particularly adept in covering the depth and breadth of the sector while maintaining a clear focus and synergy.

All of the projects within the portfolio were clearly aligned with BETO's goals and the milestones of the technology area. The Review Panel did not identify a lot of gaps in the portfolio—the recent addition of biochemical and bioproducts along with the increased focus on social indicators are two examples of previous gaps addressed since the last review. Increased communications and stakeholder engagement were also gaps that were successfully identified and addressed.

The Panel applauds the work on optimizing landscape design and notes that LUC continues to be an issue. While much of the initial assertions have been disproved, obtaining clear and rigorous scientific data will help in making meaningful contributions to this issue.

Risk mitigation is also an area that could benefit the bioeconomy. While complex, understanding various decisions and/or regulatory influences and how to mitigate

the risks associated with these actions would help to move the sector forward.

Commercialization

A successful project goes beyond the technology employed and requires an understanding of the environmental, social, and economic ramifications of the technology. That is where A&S plays a significant role. While the methodologies and tools developed as a part of this portfolio are not themselves being commercialized but are instead being offered for use publicly, the rest of the projects in BETO rely heavily on the expertise of the A&S team to help move toward commercialization. The A&S team provides the nascent technologies with the TEA, LCA, and other methodologies to determine the sustainability of the process—something most start-up technologies are unable to provide for themselves. This access to expertise not only speeds the commercialization of the technology but ensures that the process is optimized for sustainability.

In addition, the Panel observed a greater focus on communication and making the work publicly available. Examples of this included more model releases, data availability, reports and publications, greater use of the Bioenergy KDF, BIC, standards work, stakeholder meetings, and forums. Sharing of this information will help industry to move forward more rapidly and get these new biobased technologies into commercialization quicker.

The consortium approach of some of the projects was great and should be encouraged. This approach allows a wide diversity of disciplines to work together in a multidiscipline manner. But more importantly, it enables industrial involvement in the research and a stronger connection to the ultimate customers of the research.

As mentioned previously, the deliverables of the A&S portfolio go beyond knowledge generation, but incudes tool and method development. The Review Panel was pleased to see that much of this work is being released and used publicly.

Recommendations

First, investigators need to make clear where their projects fit relative to other BETO projects and the A&S Technology Area's goals. A&S leadership is currently working on mapping of all of its projects which will help visualize how each of the projects link together. It will also help visualize any potential gaps or opportunities and make clear what the ultimate value or significance the projects bring. When asked to define relevance, many PIs showed which BETO goals their project addressed. This shows that it is aligned with BETO's mission but does not make it relevant. A PI should know not only how their project fits relative to other BETO projects but how it fits in the bigger picture. A PI should be required to address what problem their work is going to solve as well as how their work will matter and make a difference. This would help to ensure that the meets an actual need and is not just intellectually exciting.

Second, while much progress has been made, there needs to be a greater focus on integration. While increased collaboration has helped drive an increase in integration, more could be done in this area resulting in more robust and multifaceted projects. This is particularly important with the maturity of many of the analytical models. The maturation of some of the models developed as part of the A&S platform will necessitate a slight shift from further tool development to the application of these tools on critical real world issues, problems, or scenarios. Achieving a good balance between further tool development and application is required.

Finally, there needs to be a clear attempt at consistency and agreement across projects especially in how sustainability is measured with a continued push to look not just at the environmental issues of sustainability, but the economic and social aspects as well. These three legs of the stool should not be treated separately but together. We applaud the leadership's efforts to include more social impacts and other hard-to-quantify impacts into

the portfolio's projects. We also applaud their impetus to strengthen communication and integrate the science generated by the program into the bioeconomy debate at the local technology and global levels.

A&S PROGRAMMATIC RESPONSE

Introduction/Overview

We thank the Peer Review Panel for their time, active engagement, and constructive review of the A&S portfolio. We appreciate the reviewers' recognition that the portfolio is designed to have significant impact and the tools and methodologies developed by A&S are used to inform decision making at strategic and project levels. The Peer Review Panel recommendations will be used to further enhance the effectiveness of the Technology Area's activities and contribution to the Office's goals.

In setting the agenda for reviewers, projects were grouped according to their general area of focus:

- Bioenergy sustainability
- Environmental analyses (i.e., water, biodiversity, and air)
- GHG/life-cycle analyses
- Market and integrative scenario analyses
- LUC modeling
- International considerations and collaborations
- Feedstock production and landscape design (both agricultural and forestry).

The 2015 Peer Review Panel provided several recommendations for the A&S Technology Area to act on, and the 2017 Peer Review Panel recognized the progress made on those recommendations. This year's reviewers specifically called out improvements in communications and stakeholder engagement, an increased focus on social indicators, and the addition of biochemicals and bioproducts in our scope. We are pleased that we have been able to continue to build an effective portfolio and that our efforts to imple¬ment feedback since 2015 have been fruitful.

The reviewers also praised the improved level of collaboration between projects. We appreciate the recognition of significant data sharing and interaction between laboratories and external partners. Researchers from multiple laboratories were co-investigators on various projects, and efforts were made to ensure that data created by one project could feed into or inform another. The reviewers noted how *BT16* volume 2 on environmental effects was a significant achievement that highlighted the depth and breadth of the tools and capabilities developed by the A&S Program. We will continue communicating these tools and capabilities to a wider audience.

Reviewers provided feedback on each project within the A&S portfolio and, in response, PIs are working to address this project-specific feedback to strengthen their future work plans. The reviewers also provided feedback to the overall A&S technology area, which was organized into three general recommendations. BETO technology managers for A&S greatly appreciate these recommendations and are already incorporating these suggestions into priorities for FY 2018 and beyond.

Recommendation 1: Clarify Where Projects Fit Relative to Other BETO projects and the Program's Goals

The reviewers called on investigators to better communicate and clarify where their projects fit into the bigger picture. We greatly appreciate this feedback, and we recognize that even if a project provides significant value, this value is undermined if the PI cannot clearly articulate the project's contribution to larger programmatic

and/or industry goals. As BETO technology managers, we will work to provide clearer guidance to PIs on how they should illustrate their relevance, and we will define clearer expectations for PIs to clearly articulate the problems they are working to solve and the impact of their work.

One effort we have undertaken over the past year is a model and tool "mapping" project that has created a holistic framework to summarize the range of models and tools in the A&S portfolio. While this effort began prior to the Peer Review, we did not yet have concrete visualizations. We now have a robust summary of laboratory modeling capabilities, as well as visualizations of those capabilities and interlinkages between modeling efforts. The database and diagrams will be used to improve communication between BETO and laboratory researchers as well as with external audiences. We envision that these diagrams will be used by PIs moving forward to show how their project relates to the bigger picture and their unique capabilities in addressing research questions, as well as how they interface with other modeling efforts.

Recommendation 2: Greater focus on integration

The reviewers, while recognizing how increased collaboration has helped drive an increase in integration, recommended continued focus toward more robust and multifaceted projects. Reviewers also noted that some of the program's analytical models have matured to the point where there should be less emphasis on development and more emphasis on application of the tools on critical real world issues, problems, or scenarios. We agree with the reviewers' recommendation to adjust focus toward application, and we have begun incorporating this into our FY 2018 plans. For example, we plan to downshift development of the Biomass Scenario Model (BSM) and instead will convene working groups involving BETO and national laboratory staff to facilitate application of BSM to address high-priority analysis questions. Furthermore, we will support efforts to publicly release the Feedstock Production Emissions to Air Model (FPEAM) so it can be applied to real world issues by decision makers. With regard to increased integration, we will continue efforts to integrate TEA and LCAs of biofuel pathways; for example, we will continue the supply chain sustainability analyses that are coauthored by ANL, INL, NREL, and PNNL, and we will apply this integrated strategy to look at more pathways that include high-value co-products.

Recommendation 3: Establish consistency and agreement across projects

While reviewers recognized the progress that was made since the 2015 Peer Review, the reviewers called for greater consistency across the projects in terms of how sustainability is measured, as well as a continued push to investigate the social and economic issues of sustainability, in addition to environmental aspects.

With regard to economic and social effects of bioenergy, A&S is already planning several analysis efforts in FY 2018 to understand and quantify the job effects and other economic benefits of advanced bioenergy. We are also pursing an integrated LCA methodology that can consider environmental, social, and economic impacts in a more holistic manner.

We recognize that greater consistency is needed not only within BETO but also across different agencies. We are now playing a larger role in the A&S interagency working groups under the Biomass R&D Board to facilitate more consistency and communication across agencies. Additionally, collaborations continue through International Energy Agency (IEA) Bioenergy, specifically on the Measuring, Governing, and Gaining Support for Sustainable Bioenergy Supply Chains project, which covers environmental, economic, and social dimensions and includes diverse international researchers and perspectives. These efforts will help facilitate more consistent terminology, methodologies, and understanding of bioenergy sustainability nationally and internationally.

OPTIMIZATION OF SOUTHEASTERN FOREST BIOMASS CROP PRODUCTION: A WATERSHED SCALE EVALUATION OF THE SUSTAINABILITY AND PRODUCTIVITY OF DEDICATED ENERGY CROP AND WOODY BIOMASS OPERATIONS

(WBS #: 1.1.1.101)

Recipient:	North Carolina State University
Principal Investigator:	George Chescheir
Project Dates:	9/30/2010–9/30/2016
Project Category:	Sun-setting
Project Type:	FY 2010—Feedstock Sustainability: DE-FOA-0000314
Total DOE Funding:	$2,092,892

Project Description

The goal of the project is to develop and disseminate science-based information for sustainable production of biofuel feedstock in a forestry setting in the Southeast. The project seeks to quantify the impacts of interplanting switchgrass between rows of loblolly pine trees on hydrology, nutrient dynamics, soil quality, flora and fauna populations, and habitat quality using watershed and plot-scale experiments. In addition, the project documents the productivity of the system and the additional costs related to site preparation, planting, fertilization and harvesting the interplanted switchgrass. The project uses the field data to develop and test watershed and regional scale models that simulate the competition between trees and switchgrass and predict switchgrass yield as well as the quantity and quality of water draining from the system. Field experiments showed that some impacts to hydrology, water quality, soil quality, and biodiversity were observed in response to field operations to establish switchgrass, but impacts

Weighted Project Score: 8.1

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

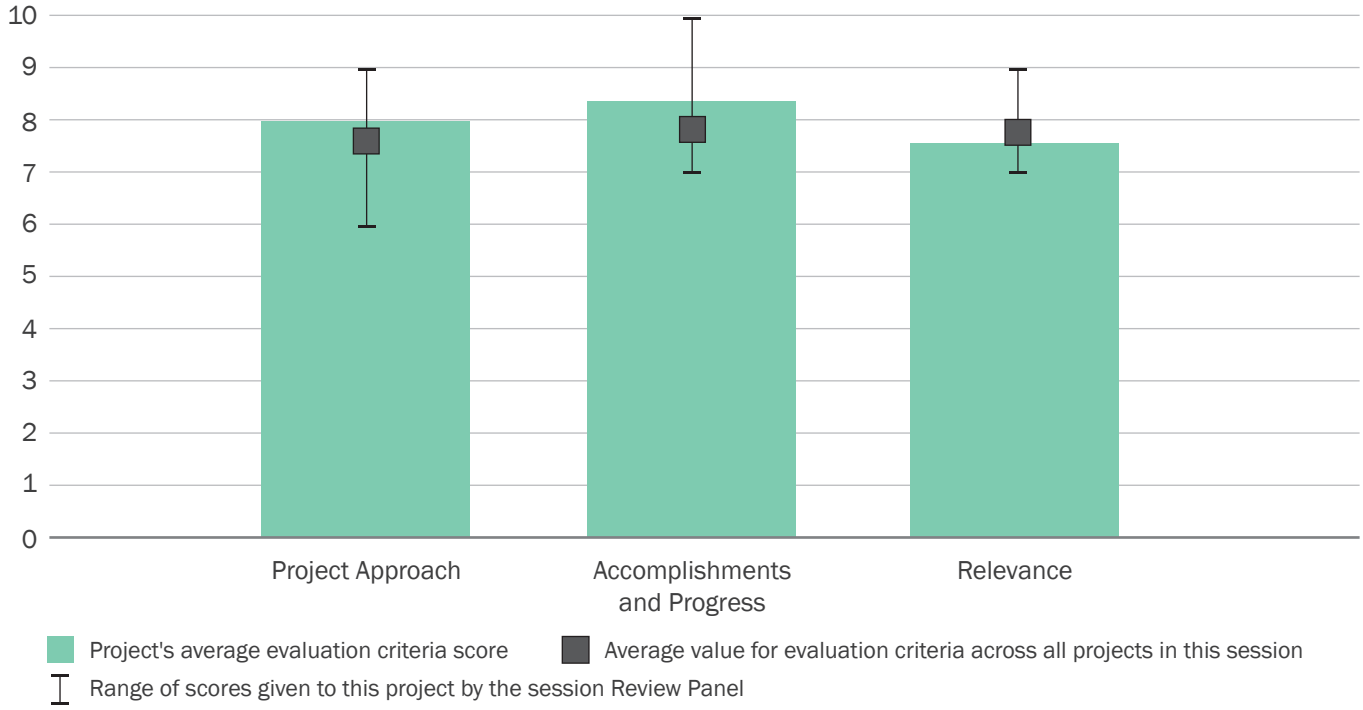


Photo Courtesy of North Carolina State University

were small and short lived. Best management practice (BMP) guidelines were developed for environmental sustainability. The project, however, also documented the limitations of switchgrass production in the forestry setting, and the challenges and increased costs arising from this practice. These challenges led to the conclusion that intercropping switchgrass with pine trees is not economically feasible in the current economic climate.

Overall Impressions

- Switchgrass was selected for intercropping between pine trees. While in hindsight, this was not an optimal choice, the idea of using the land area between the trees to provide short-term income from an otherwise long-term investment has its merits.

  The project was highly leveraged and received good collaboration between a wide array of governmental, academic, and industrial partners. The management approach was clearly defined with regular meetings and an unrestricted flow of information and ideas between collaborators. The project was ambitious and involved extensive data collection. It looked at the hydrology of different energy crop production systems, quantified the nutrient dynamics of energy crop production systems to determine the impact of these systems on water quality, and evaluated the impacts of energy crop production on soil structure, fertility, and organic matter content. The diversity among the local flora and fauna populations were also accessed among other things. While in the end, the study found that intercropping with switchgrass was not economically viable, it is my hope that the extensive data collected during this study will be used to inform subsequent studies. Understanding the potential for intercropping of a variety of energy crops in different climates and geographies could prove useful in optimizing land use in the future and providing the quantities of biomass required by the growing bioeconomy.

  While this project is winding down, the large amount of data collected during the project on everything from hydrology and water quality to soil quality and biodiversity will serve as a foundation for future studies. Also, the application of these data to best management practices and lessons learned will also prove beneficial. It would be helpful to future researchers to know why the team chose switchgrass initially and, if you had it to do over, what would you have picked knowing what you now know. Also, instead of growing an energy crop with the intention of harvesting the crop cost-effectively, what advantages would there be to simply planting a cover crop at the same time the trees are initially planted or collecting what comes up naturally?

- I feel it is important to say something about this project as an example of one that achieved negative results. Too often this may be perceived as a "failure." It is not. It is good science.

  Sometimes there is a tendency when a researcher reaches a negative result to think that s/he should have anticipated the outcome before s/he began, and not incurred the resources to conduct the experiment. I have, in some instances, questioned whether some other projects in their early stages are barking up the wrong tree. The fact that this work passed earlier reviews, not to mention that it was conducted in collaboration with a leading forest products com-

pany, shows that the questions it poses were deemed worth considering.

So, I think it is extremely valuable to have these sort of carefully conducted tests--sometimes knowing what not to do is as valuable as knowing what to do (maybe sometimes even more so). I am going to some length on this, because there is a great deal of concern now in science generally about rampant "p-hacking" (fudging results to make it look like they're "better" than they are). I think it would send a terrible signal to suggest work like this is not as useful because its results do not support a particular thesis. There is a great deal—arguably too much--of enthusiasm for identifying win-win solutions to environmental and energy problems. These researchers are to be applauded for doing careful work and reporting it candidly, especially if it does not confirm optimistic projections.

- Well thought-out experimental design with extensive data collected at the watershed and field scale on many different aspects of sustainability.
- The project did an impressive job of systematically conducting field and watershed measurements and modeling watershed effects of the impacts of intercropping pine with switchgrass across a variety of water, nutrient cycling, soil, and biodiversity indicators. The project also has an impressive number of publications across a range of topics. One issue is that it is not clear the researchers considered changes in above ground carbon which are essential for sustainability assessment, including the effects of the disturbance to establish the cropping system. Otherwise, the study seems exceptionally rigorous and comprehensive. The study's rigor with measurement of different site-level treatments and watershed impacts is a model for other assessments.

  While intercropped forestry systems could be an important bioenergy pathway, the major question is why intercropping of switchgrass with pine was chosen of the possible technical interventions. This was identified to be non-economic. If there are other systems that might be more commercially viable, perhaps an initial screening or set of quick analyses might have prioritized another system for in-depth study given the ultimate goal to promote commercial bioenergy development.
- The project produced a large dataset and provides insights into the potential benefits and issues associated with real world systems combining woody and perennial grass cultivation systems. The project funded a large research team that collected a substantial amount of data. It is important that the data from this project be documented and shared publicly for use in future analyses.

  The project would benefit from striving to also provide information about the economic viability of the system and the interplay between environmental and economic factors. The project is narrow in its focus on the specific intercropping systems considered and the presentation didn't make clear how the results can be extrapolated to decision making for other proposed bio-feedstock production schemes.

PI Response to Reviewer Comments

- We would like to thank the reviewers for their insightful comments. These comments will help guide us as we finalize manuscripts that summarize this project and offer recommendations for the way forward.

  Many of the lessons learned were presented in a published manuscript that summarized the potential and challenges of implementing switchgrass

[37] J. Nettles, P. Birks, E. Sucre, and R. Bilby, "Sustainable Production of Bioenergy Feedstock from the Industrial Forest: Potential and Challenges of Operational Scale Implementation," *Current Sustainable/Renewable Energy Reports* 2, no. 4 (2015): 121–127, doi:10.1007/s40518-015-0042-9.

production in the forestry setting.[37] This manuscript laid out many of the factors considered in the original proprietary process of selecting the methods to produce biofuel feedstock in forests. Potential issues considered were energy and feedstock market demands; government policy, mandates, and incentives; environmental effects on biodiversity, water, and soil; carbon fate and accounting methodology; seed source and availability; planting methods and establishment success; switchgrass productivity; competition between pine and switchgrass; equipment and contractor availability; harvesting logistics and efficiency; and transportation costs. When these decisions were being made in 2008, projected market demands, government policies, and technological advancements were somewhat different than those experienced during the life of this project. Nevertheless, the manuscript reports the operational challenges (i.e., number of field entries and equipment constraints), productivity limitations (i.e., impacts of shading, excess moisture, and soil fertility and pH), environmental impacts (i.e., soil compaction, erosion, biodiversity, and nutrient and carbon losses), and economic trade-offs between productivity and environmental impacts (i.e., seedbed preparation versus erosion, delay between tree planting, and switchgrass planting and water quality). Preliminary results of the manuscript suggest that intercropping switchgrass with pine trees can be environmentally sustainable with careful adherence to forestry BMPs, but the productivity of inter-planted switchgrass is less than in agricultural settings despite the increased costs of production.

The effect of switchgrass intercropping on soil carbon and microbial activity was reported in a manuscript by colleagues conducting an allied study not funded by BETO.[38] The study found that total soil carbon in the top 15 cm of the soil profile was lower under intercropped switchgrass two years after planting than under conventional pine plantations. Microbial activity, however, was greater under intercropped switchgrass indicating active microbial biomass, which is a precursor soil carbon formation. Longer term studies will need to be conducted to evaluate if increasing microbial biomass offsets the initial decline in carbon under switchgrass.

We are finalizing a manuscript that will more completely summarize the lessons learned in this project and propose alternative systems for more effective biofuel feedstock production in light of recent market conditions and the most recently analyzed data. While the number of systems studied in this project was limited, the range of intensities of feedstock production was quite wide. This allowed us to observe a range of results and to use those observations to develop and test our models. We believe that more effective alternative systems for producing biofuel feedstock in forestry settings will fall within the range of intensities studied in this project. That is, more effective alternative systems will likely involve less-intensive field operations and a feedstock that requires less site preparation and inputs over and above those typically used in conventional forestry.

[38] M. S. Strickland, Z. H. Leggett, E. B. Sucre, and M. A. Bradford, "Biofuel Intercropping Effects on Soil Carbon and Microbial Activity," *Ecological Applications* 25, no. 1 (2015): 140–150, doi:10.1890/14-0285.1.

PATHWAYS TOWARDS SUSTAINABLE BIOENERGY FEEDSTOCK PRODUCTION IN THE MISSISSIPPI RIVER WATERSHED

(WBS #: 1.7.17)

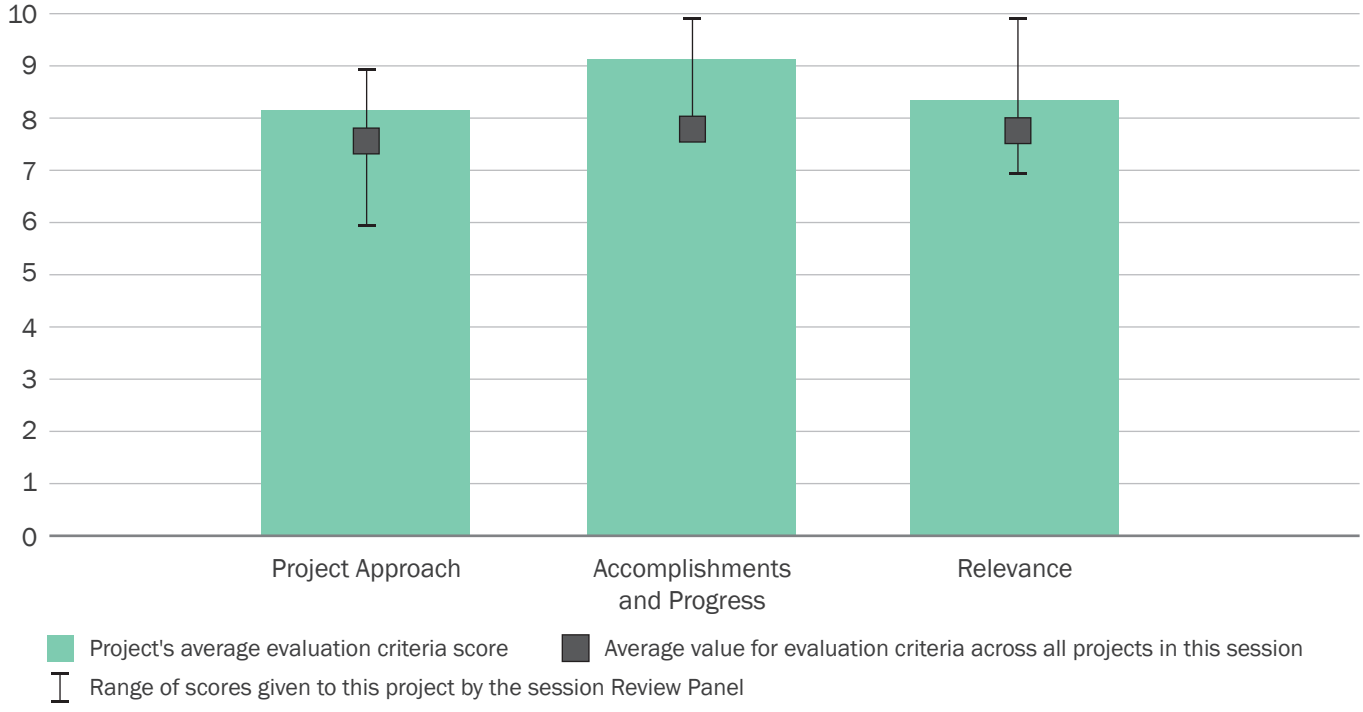
Recipient:	University of Minnesota
Principal Investigator:	Jason Hill
Project Dates:	9/30/2010–12/31/2015
Project Category:	Sun-setting
Project Type:	FY 2010—Feedstock Sustainability: DE-FOA-0000314
Total DOE Funding:	$790,943

Project Description

The growing bioeconomy holds great promise for improving the sustainability of transportation, yet many of the environmental effects of industrial-scale biomass production are largely unknown. This project seeks to reduce this uncertainty by employing an ecosystem service framework to evaluate various biomass sources and their placement on the landscape in the economically important and agronomically diverse Mississippi River Watershed. Over the course of this five-year research project, we have explored the effects of biomass production on climate change, air and water quality, biodiversity, and water and energy use. Among our key findings, we have demonstrated the importance of air quality in bioenergy decision making, identified fertilizer use as a primary target for intervention, shown near-source evapotranspiration recycling for perennial herbaceous crops, and established the strong dependence of impacts on biomass production location. Our project has led to novel advances in environmental assessment including the modeling of two-way interactions between bio-

Weighted Project Score: 8.8

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



sphere and climate, reduced-form air quality modeling, and advanced methods of spatial LCA and of ecosystem service valuation and incorporation of uncertainty therein. Our work, which has been published in over a dozen peer-reviewed papers, has led to numerous academic collaborations and has received widespread interest from agricultural, industrial, and governmental stakeholders.

Overall Impressions

- The overall goal of this project was to use an ecosystem service framework and integrated modeling approach to evaluate potential environmental effects of various biomass sources and their placement on the landscape. The goal was to inform the growing bioenergy industry to make choices with greater sustainability. The project required minimal management since the team was small and co-located. However, greater collaboration with other BETO researchers may have proven useful. Overall, the project accomplished a great deal including demonstrating the importance of air quality in bioenergy decision making, identifying fertilizer use as a primary target for intervention, and showing near-source evapotranspiration recycling for three different perennial herbaceous crops. Key findings were that the environmental impacts of biomass are highly location specific at a regional level and that switching from urea fertilizer can lessen health impacts. The project covered a wide range of topics and impacts, and the models generated should be useful in future research. The work from this sun setting project has been widely published in over a dozen peer-reviewed papers. In addition to the data generated and the models developed, I think one of the greatest impacts has been in helping BETO and the bioeconomy in general, to look at the issue of sustainability from a different lens. Dr. Hill's findings have helped to stimulate discussions and have shown that where and how you produce biofuels matters. Small changes such as switching fertilizers can have significant impacts. I hope that this research will serve to help the industry make more informed decisions.
- Interesting project output, filling an important translational role between fundamental technical research and necessary policy dialogue. I would have appreciated a discussion of how the individual analyses fit together and the story they collectively tell, as there is potential that the contribution of this project is more than the sum of its parts.
- This project has provided exceptional value for investment. By leveraging existing models to answer questions about biomass production, it has addressed questions that might otherwise not have been considered, and done it at a modest overall expenditure. A good portfolio of overall research might contain a handful of projects that overlap on important issues, as well as some that delve into less-explored matters that might still be important. This work does a little of both, with perhaps more emphasis on the latter. In this regard, it represents a cost-effective investment.
- The project is centrally relevant to BETO's goals of assessing sustainability along multiple criteria. Understanding the heterogeneous nature of environmental impacts is also critical and it would be useful to further explore the implications of alternative policy and market scenarios. It would also be valuable to understand the scale dependence of the results and of associated uncertainties. This is one of the most productive projects in the BETO portfolio in terms of high-caliber publications, especially given the limited personnel. This supports the value of including academic partners.

  It will be important to compare results and maximize learning between the models developed in this project and those in other projects on air, water, and other impacts in the BETO portfolio (e.g. WBS

#s 4.2.1.10, 4.2.1.30, and 4.2.1.40). It would also be beneficial to ensure coordination between this project and the ORNL project (WBS # 4.2.2.40) to define sustainability metrics based on multiple criteria. Additionally, it would be helpful to specify success around a practical application to help inform a stakeholder decision. It would also be helpful to further spell out links with other projects in the portfolio. Finally, it would be valuable to explore ways the models and/or underlying data can be shared on the Bioenergy KDF or another linked open-source platform.

- This is an example of a well-run and successful research effort. The project asked and addressed important questions using appropriate methods that built on previous work and resulted in the dissemination of knowledge back to the public and biofuels research community.

PI Response to Reviewer Comments

- We thank the reviewers for their comments and positive evaluation. Our project has ended, but we are continuing to publish its results. For example, the Intervention Model for Air Pollution was published on April 19, 2017.[39] We look forward to continuing to engage with BETO personnel as we carry this work forward in other projects.

[39] Christopher W. Tessum, Jason D. Hill, and Julian D. Marshall, "InMAP: A Model for Air Pollution Interventions," *PLoS ONE* 12, no. 4 (2017): e0176131, https://doi.org/10.1371/journal.pone.0176131.

GREET DEVELOPMENT AND BIOFUEL PATHWAY RESEARCH AND ANALYSIS

(WBS #: 4.1.1.10)

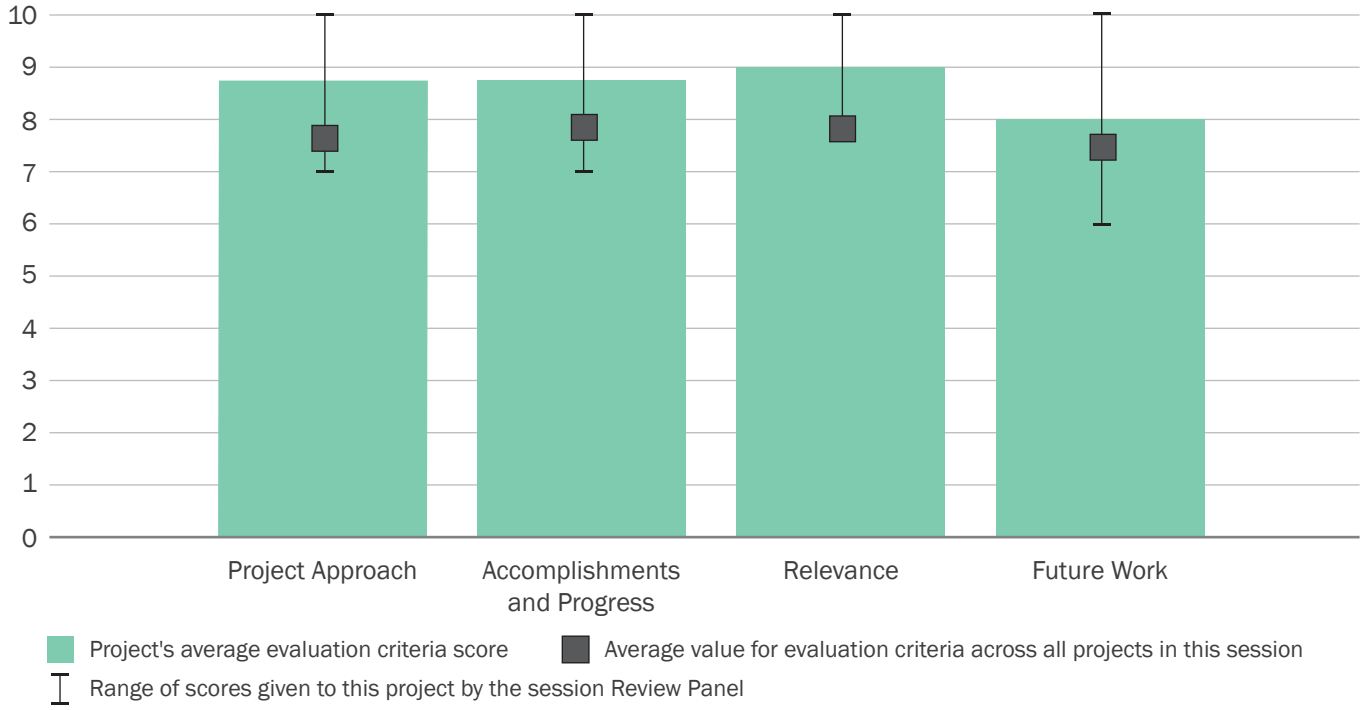
Recipient:	Argonne National Laboratory
Principal Investigator:	Jennifer Dunn
Project Dates:	10/1/2014–9/30/2017
Project Category:	Ongoing
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$1,275,000
DOE Funding FY 2015:	$1,462,000
DOE Funding FY 2016:	$1,462,000
DOE Funding FY 2017:	$262,000

Project Description

Since 1994, with DOE support, ANL has been developing the GREET model for LCA of vehicle/fuel systems. Of the more than 100 vehicle/fuel technology options in GREET, biofuel production pathways are an important group. With BETO support in the past 2.5 years, ANL has used the GREET model to examine the energy and environmental impacts (e.g., petroleum use, greenhouse gas emissions, criteria air pollutant emissions, and water consumption) of various biofuel pathways with different feedstocks and conversion technologies. ANL has updated and upgraded the GREET model, added new biofuel pathways, and examined critical LCA issues such as LCA system boundary, co-product methodologies, and indirect effects such as LUC. With nearly 30,000 registered GREET users, ANL continues to interact with key stakeholders including government agencies, fuel/technology developers, and non-governmental organizations to advance understanding of energy and environmental effects of biofuel technologies and utilization.

Weighted Project Score: 8.6

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



Overall Impressions

- BETO has long supported the development of the GREET model, a LCA tool used to quantify the energy and environmental impacts of biofuels. Today, GREET provides a well validated and rigorous tool to advance the understanding of biofuel sustainability. It is used broadly by the LCA community with nearly 30,000 users and serves as an enabler for policies such as the RFS and the Low Carbon Fuel Standard program. It provides a consistent and comprehensive format to assess the benefits of various biofuels pathways. The project displays a high level of collaboration and integration. Much has been accomplished since the last review. GREET has undergone additional model development including the modeling of LUC and soil organic compound change for biofuel feedstocks. GREET also served as a major contributor to the *BT16* volume 2 sustainability report. Life cycle water consumption and additional co-feedstocks and co-products were added to the model. Of particular interest was the LCA expansion for various production scenarios for algae. This integrates nicely with the efforts BETO is making in the algae space.

  GREET provides a platform to integrate the LCA of biofuel pathways to address their overall energy and environmental benefits which is critical for BETO and the rest of the bioenergy community. Future work includes continuing to address farming management practices and their impacts on soil organic compound for biofuel feedstocks, continuing to expand key GREET modules and GREET functionalities, and continuing to monitor and expand emerging biofuel conversion technologies. An effort will be made to regionalize the GREET well-to-wheels analyses of criteria pollutants and water stress assessment as well as extend LCA for different algal cultivation and fuel processing pathways to provide R&D guidance to BETO and the biofuels community. It will be important to remain focused on the most critical issues. I do feel, however, that adding biobased chemical and biobased products to the model would be useful as these materials are enablers of the bioeconomy with many early examples already in commercial production.

- GREET is ubiquitous in biofuel sustainability analysis, and the project team continues to produce relevant and necessary analysis. My only suggestion is that the project team communicates more clearly how they will continue to pursue the most critical issues and analyses in future work.

- While, taken as a whole, GREET represents a tremendous achievement, it in its current state it also raises some important concerns for the management of the BETO portfolio. Something in excess of $7 million has been spent to date in the development of GREET and it appears to have been money well spent. As the final roughly $1.5 million allocated to the project is committed, however, it begs some questions:

  - After spending as much as has been, what remains to be done?
  - If the answer to the previous question is “a lot,” were earlier priorities chosen wisely?

  If it’s the case that earlier spending priorities were appropriate but a lot still remains to be done, what is the comparative advantage of doing the work under the auspices of the GREET platform, as opposed to by others, after which results might be integrated into GREET?

  It is not entirely clear to me, however, how important the work now being taken up for GREET is (albedo?). Some scrutiny should be applied to ongoing expenditures. Related to this, several other projects refer to the use of their results in GREET. This testifies to the usefulness of GREET as a platform, but complicates the task of the reviewer. How

should credit be assigned between the creators and maintainers of the GREET platform itself and the teams contributing to its extensions?

- This project is of central relevance to BETO's goals by providing a consistent comparison platform to assess sustainability across multiple dimensions. Moreover, given the wide recognition and use of GREET, it is important to ensure ongoing improvement to reflect the best available science and the project should be commended for striving to do so. Particular high priorities in this respect are the identified next steps of assessing the temporal dynamics of forest feedstocks under alternative assumptions, and comprehensively evaluating the issues of carbon neutrality and additionality. The inability to address these issues left notable gaps in *BT16* volume 2 report, and it will be important to able to continue developing capacities to be able to address them with within the BETO portfolio.

  To ensure the best available information, it is also essential that the project draw on the best evidence from the other parts of BETO portfolio.

  A key consideration is how best to characterize and report uncertainties and spatial (and temporal) heterogeneity of results to provide a more detailed picture of life cycle impacts appropriate for different policy objectives.

  Integrating GREET and associated visualization could also be a priority for the Bioenergy KDF.

PI Response to Reviewer Comments

- ANL has maintained regular communication with BETO sponsors and interactions with other national laboratories and the bioenergy community. Our analysis priorities are determined annually based on these efforts. For example, our LCA work is designed to serve BETO's 2016 *Multi-Year Program Plan*, 2016 *Strategic Plan for a Thriving and Sustainable Bioeconomy*, and State of Technology Assessment, as well as to address emerging issues government agencies and the biofuel community bring into discussion.

  Thanks [to the reviewers] for bringing up the BETO resource commitment vs. critical issues in the LCA space. This single annual operating plan is a significant resource commitment by BETO. However, this annual operating plan could have been separated into several topical areas, each of which could require significant efforts to address (e.g., the assessment of indirect effects such as LUC, soil organic compound dynamics, forest feedstock carbon dynamics, the algae technology pathway assessment, and regional water and air emission effects). While GREET development is part of this annual operating plan, it is not the driver of analytical topics and issues. In fact, it is analytical topics and issues that determine ANL research priorities and GREET model development is our last step so that the bioenergy community can use GREET to examine the issues we have analyzed.

  We agree with the suggestions as our future plan reflects some of these comments. Speaking of characterizing and reporting uncertainties and spatial (and temporal) heterogeneity of LCA results, we have addressed uncertainties and variations in GREET LCAs methodologically and analytically. We will need to continue this effort to address regional variations at a finer resolution as we move to address environmental issues such as criteria air pollutant emissions and water consumption of biofuel feedstocks and conversions. Note that one of the main goals of GREET.net development is to address and display spatial heterogeneity of LCA results. The temporal heterogeneity, on the other hand, has not been addressed as thoroughly as spatial variations, partly because time series data are often difficult to obtain, especially for newly emerging technologies. Extra efforts should be made on this aspect in the future.

STRATEGIC ANALYSIS SUPPORT

(WBS #: 4.1.1.30 and 4.1.2.30)

Project Description

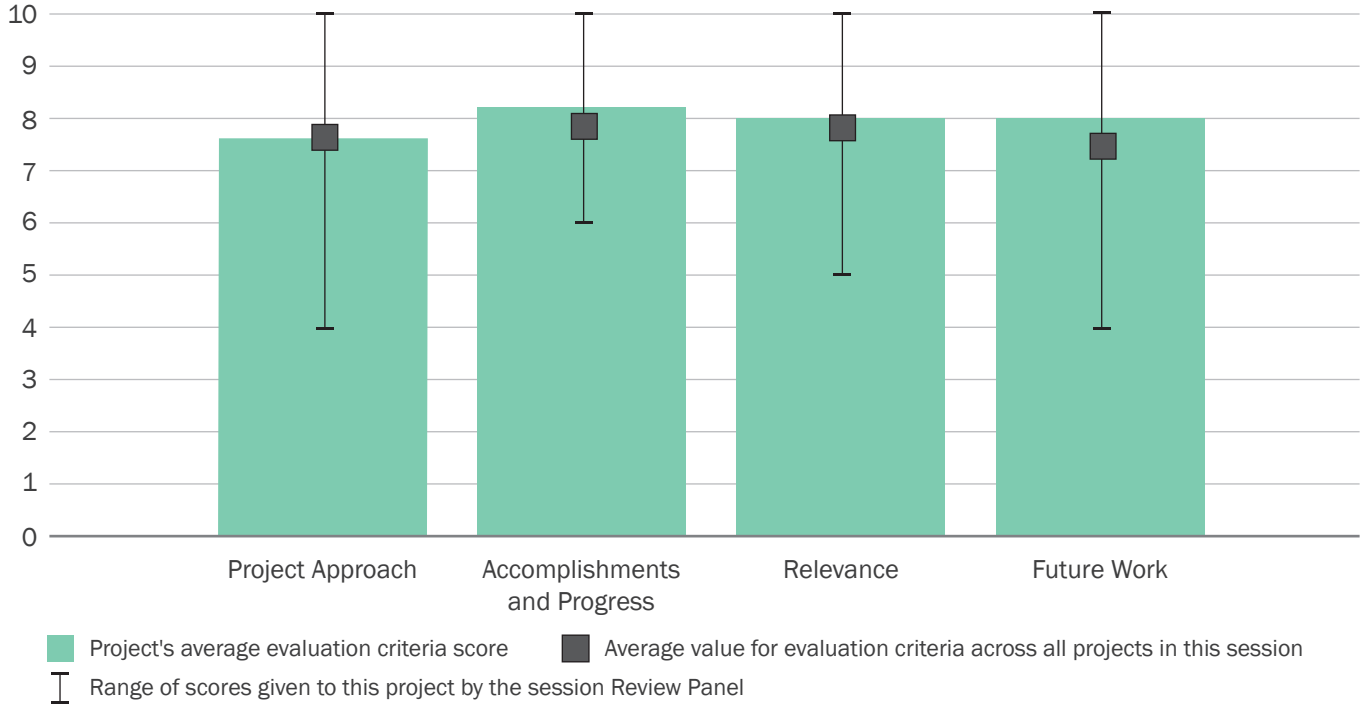
Recipient:	National Renewable Energy Laboratory
Principal Investigator:	Mary Biddy
Project Dates:	10/1/2010–9/30/2018
Project Category:	Ongoing
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$600,000
DOE Funding FY 2015:	$545,000
DOE Funding FY 2016:	$650,000
DOE Funding FY 2017:	$500,000

The NREL strategic analysis project portfolio encompasses a wide set of analytical tools and expertise in support of the BETO. Started in 2010, this set of projects work to develop models and methodologies used to assess the technical, economic, and societal impacts of the development and implementation of bioenergy technologies. These models serve as an analytical basis for program planning and evaluation of progress. Specifically, these efforts include (1) an estimation of job growth and the economic impacts of bioenergy production; (2) the TEA of the strategic expansion of hydrocarbon fuel technologies, including to jet fuel production; (3) a market analysis to identify key drivers and hurdles for near-term industry growth of bio-derived chemicals; and (4) assessing the value of bio-derived blendstocks to petroleum refiners.

Utilizing high-quality data that are thoroughly documented and vetted is critical to the success of these tasks. We work with key stakeholders (e.g., policymakers, bioenergy technology developers, and investors) in developing and reviewing the results of these analyses. Uncertainties associated with the analysis efforts are clearly defined and quantified.

Weighted Project Score: 8.0

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



Overall Impressions

- The goal of the Strategic Analysis Support group is to develop and utilize an array of analysis tools to support the strategic direction of BETO and understand the development of a biomass economy. The types of analyses range from assessing the current and future market drivers for the production of biomass-derived chemicals to providing comparative economic analyses for jet fuel production pathways. This group utilizes a wide variety of tools and expertise. The project is well managed with clearly defined objectives and milestones. The use of go/no-go decisions has proven effective. Communication and collaboration is critical to the successful hand off of the information in support of other BETO projects. The group has made a great deal of progress since the last review. This progress includes a market report analysis and publication on bioproducts to enable biofuels, the development of TEAs for understanding jet fuel production, support for conversion R&D strategies to understand fuel quality valuation, and jobs and economic development impact (JEDI) case studies to identify key factors that contribute to job growth. Each of these projects is significant by themselves. Together they represent an enormous amount of work which helps to highlight the impacts of the emerging bioeconomy and outline specific hurdles or gaps for further development by BETO and industry. One good example of this is the market analysis report for the production of bio-derived chemicals. This report identified 27 biomass-derived products which were down-selected to 12 products based on market potential. The emerging area of biobased chemicals and bioproducts has the potential to produce some short-term wins that could spill over to the broader biofuels market. This report was a great example of the type of research done by this group.

  The relevance of this work is in its ability to provide credible results to assist decision makers in the bioenergy space by applying appropriate analyses and models. The group provides a go to group for BETO whenever the need arises. The work is often started here and then passed off to others. They have proven they have the ability to provide a quick turnaround on BETO requests. I see this group as being a key enabler of the Co-Optima initiative, and a close collaboration between the two groups is important. Future work includes case studies with JEDI to consider the effect on income distribution, the comparison of biofuel hydrocarbon pathways for near-term scale-up, the development of TEAs for understanding waste stream upgrading, and the assessment of refinery economics due to biofuels blending stream displacement. Given the current interest in job creation, further refinement of the JEDI model to include an analysis of job "shifting" and job loss would give a more complete picture and strengthen the validity of the model.

- This project has yielded obvious accomplishments, but it is unclear how the project strategically aligns with other BETO-funded efforts and whether the project is uniquely qualified to tackle the specific future analyses identified. Perhaps this was a function of the presentation and materials provided to the reviewers, as responses to questions asked by the Review Panel helped address this important issue somewhat.

- This project provides a comprehensive analysis of the economic viability of biofuel and product development. My sense is that the treatment of the demand side of prospective markets is more qualitative than that of the supply side, but this seems appropriate given what are probably the greater uncertainties in the development of potential product markets. The supply side analysis largely takes an "engineering" approach, but again, this is reasonable given the lack of data on the development of required technologies. Employment analysis is always problematic, as one should consider not only

the number of people employed in a new industry, but also the numbers displaced in old ones which the project considers in its future plans.

- Overall, this project seems to have delivered valuable quick-turnaround analytic and modeling capacity to BETO. The project seems well integrated to feed into other BETO projects, including GREET and Co-Optima. Showing the data interconnections among projects would help demonstrate value. Also, it would be valuable to ensure analyses and tools are disseminated on platforms such as the Bioenergy KDF and BIC.
- This is an exemplary project. It is asking the right questions, engaging a broad set of stakeholders, managing the project confidently and collaboratively, working closely with other DOE laboratories, and clearly planning next steps based on critical gaps in understanding. Moving forward, this project should continue to engage stakeholders, looking for additional stakeholders to further strengthen the analysis and expand the broader impacts, and to identify the next key knowledge gaps to inform decision making for policy, investment, and other strategic purposes.

PI Response to Reviewer Comments

We thank the reviewers for their helpful feedback and suggestions. We will continue to work to ensure the analyses and tools developed under this project are disseminated. To start, these project outcomes and models will be posted on the Bioenergy KDF and BIC websites. Moreover, this project strives to provide BETO with critical information and tools to address key questions in support of the strategic direction of the office. This project supports informational needs for a range of BETO-supported projects including GREET and BSM. It is our goal to continue to support our strong collaborations both within the national laboratories (with GREET and BSM) and externally through collaborations with industry and other government agencies. We also plan to integrate details of our bioproducts analyses into the Bioenergy Market Report supported by the A&S Technology Area. Additionally, through our integration with the Co-Optima initiative, there are ongoing efforts to develop methods to estimate ‘net’ jobs analyses which will be incorporated into this project in the future.

REFINERY INTEGRATION

(WBS #: 4.1.1.31 and 4.1.1.51)

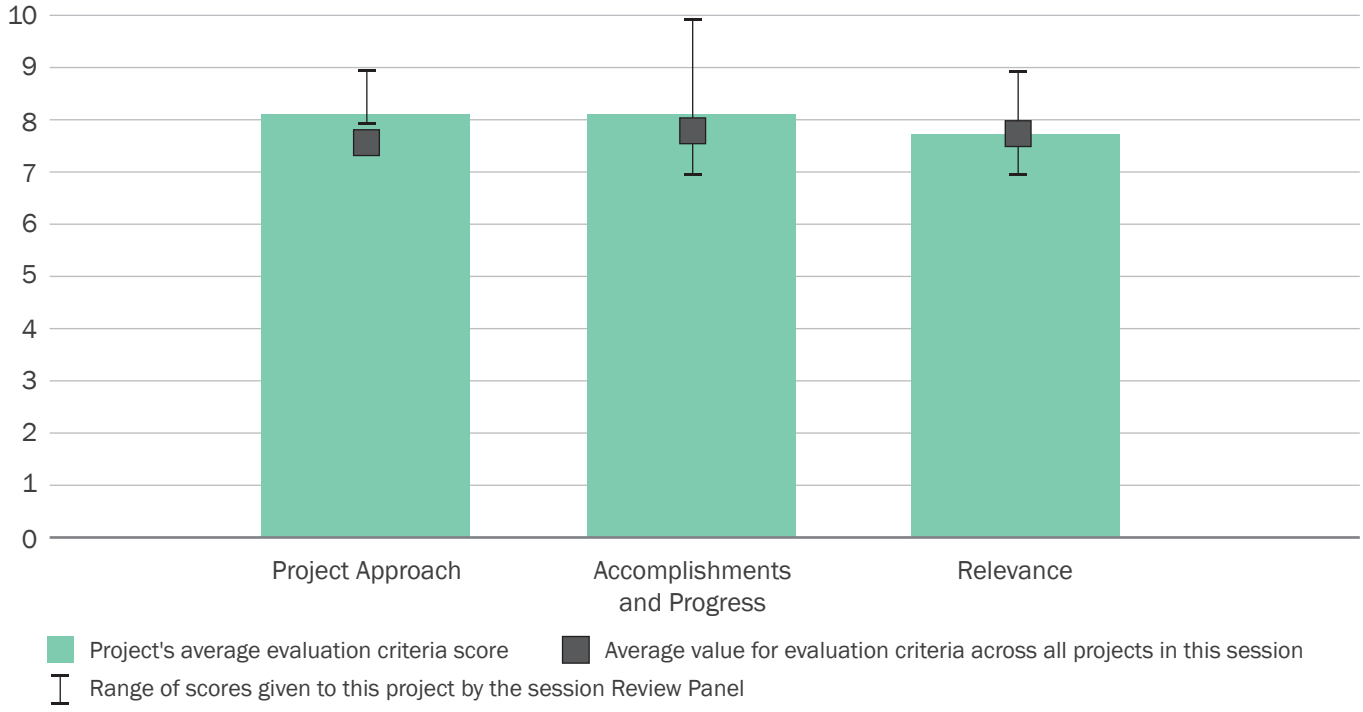
Project Description

The project purpose is to evaluate and understand the economic incentives and key cost drivers associated with use of existing refinery infrastructure to produce biofuel hydrocarbon blendstocks. All biofuel design cases are based on standalone plants processing biomass to produce a finished fuel blendstock. However, use of existing infrastructure through integration with petroleum refineries is a means to reduce biofuels production costs. At the start of the project no tools existed to assess the impact of co-processing bio-intermediates with conventional petroleum. The project builds upon separate PNNL and NREL efforts to identify and develop synergistic opportunities for integration of biomass-derived hydrocarbons into existing petroleum refineries. It directly addresses barrier "Petroleum Refinery Integration of Intermediates." This project identifies risks, key hurdles, uncertainties, and further R&D needed for coprocessing of a range of bio-derived intermediates including pyrolysis bio-oil, algal hydrothermal liquefaction bio-oil, and algal and biochemically produced lipids. The models completed within this project are AspenPlus models for hydrocracking and fluidized

Recipient:	Pacific Northwest National Laboratory, National Renewable Energy Laboratory
Principal Investigator:	Sue Jones, Mary Biddy
Project Dates:	10/1/2011–9/30/2017
Project Category:	Sun-setting
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$450,000
DOE Funding FY 2015:	$400,000
DOE Funding FY 2016:	$400,000
DOE Funding FY 2017:	$0

Weighted Project Score: 8.1

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



catalytic cracking, and Aspen HYSYS hydrotreating models. Each model was evaluated with and without biomass-derived intermediates. Preliminary modeled results and costs were reviewed by refining contacts and catalyst vendors, and that feedback was incorporated into the cost and performance models.

Overall Impressions

- The goal of the Refinery Integration team was to develop detailed process models of three key petroleum refining conversion systems for converting mixtures of conventional and biomass-derived intermediates and use these to identify costs, opportunities, technical risks, information gaps, and research needs associated with coprocessing. Despite having the work split between two sites, the project was well managed with regular meetings and conference calls that leveraged the capabilities at both laboratories. Because of the nature of the work it was critical to engage outside stakeholders. The feedback obtained by the team from refining experts was necessary to ensure that the models and methods were reflective of the actual refinery operations. While using current refinery infrastructure to co-refine bio-derived materials makes sense, a lack of understanding of the economic viability, value proposition to the petroleum refiner, and technical risk for upgrading bio-derived intermediates remains. This project sought to answer those questions. They did so by developing a suite of models to understand the impacts, opportunities and gaps associated with co-processing. These were first-of-a-kind process models of the hydrocracker, fluidized catalytic cracker, and hydrotreater looking at a variety of biomass intermediates including lipids and hydrothermal liquefaction biocrudes.

  Understanding the potential benefits to the refiners helps to determine whether or not co-processing is a viable option and represents a win-win on both sides. It will also help to address the volumes required to make this cost-effective and worth the risk to the refiner. Certainly, things like reduced sulfur content could help offset the presence of oxygenates and the high acidity normally inherent in bio-oils. However, understanding best practices such as the level of stabilization or upgrading needed prior to entry at the refinery is important. Understanding how much volume is needed and how to optimize the system would also be interesting. While this project is winding down, the models developed in this project will be used in other BETO projects. One such study would be to use the model to address the impact of algal oils if and when that technology ramps up. A highlight was the use of the models to look at the impact of the BT16 scenarios. For the 2017 and 2022 timeframes using the $60 and $80/ton scenarios, the models showed that 8–14 billion gallons per year of bio-oil-based production could be made using the least costly route.

- The project seems to have satisfied its objectives. Its goal was defined to be sufficiently limited, and work under the project seemed reasonable to achieve the outcomes set. I appreciate the efforts to transfer tools to other BETO projects and to inform external stakeholders.

- This seems a well done and potentially useful study of the potential to use existing refineries to process biomass feedstocks and their intermediate products. The only real concern I have is that the terms of the analysis be clarified. Specifically, it is important to know if, first, biomass and fossil-derived feedstocks could be used interchangeably, or, in the extreme, miscibly, so as to avoid shut downs for switchovers. Also, it is important to be clear about whether the opportunity costs of foregoing refining of one feedstock is incorporated in the cost of treating the other. I believe that these are both dealt with, but again, clarification would be helpful.

- This seems like a well-defined technical analysis but the larger contribution requires more work to communicate.

  It would be helpful to flesh out some initial hypotheses for why biorefinery integration could be a viable pathway and what it would take to achieve this. Then the findings of the study could be used to directly test these ideas and suggest potential policy or other interventions.

  The economic break-even analyses seem particularly useful to a policy audience. Key questions are how generalizable they are and how regionally and technologically specific they are. Finding a way to communicate these economics would be very helpful in the dissemination of findings including potentially through platforms like the KDF or BIC. It would also be interesting to consider the portfolio diversification and risk-hedging benefits of biofuels, as per study done with WBS# 4.1.2.41 to understand how this could affect the economics.

- This project is relevant for BETO's mission and considers likely pathways for the integration in our existing fuel supply infrastructure. This project provides new tools for evaluating refinery operation with bio-inputs.

  A strength of the project is the fact that it produces first of their kind chemical process models for integration of bio-feedstocks into refinery operations. The collaboration between NREL and PNNL strengthens the output of this project. The project also engaged suitable reviewers from industry to check the quality and validity of the models. The project met all of its milestones.

  It is important to ensure the studies performed in this project are followed through the publication process so they are made available to other researchers for reproduction of results and to be further developed. The publication of the Aspen models is another benefit of the project and it is important to ensure this happens.

PI Response to Reviewer Comments

- We thank the reviewers for their helpful feedback and insights. We plan to build on the foundational work that has begun in the A&S Technology Area project and transition these efforts to support planned experimental work under the core-conversion platform efforts. The feedback provided by the reviewers will be incorporated into these future efforts to address details that could not be dealt with in this project either because of data or time limitations. The anticipated NREL/PNNL experimental project is aimed at addressing a range of issues including, to name a few, the degree of stabilization needed, the impact of different types of processing to produce the bio-intermediate, and miscibility limitations. It is anticipated that the planned NREL-PNNL experimental project will help to fill the data gaps that were identified in this initial A&S project. The related future analysis work will be carried out within existing annual operating plan projects.

RESOURCE ASSESSMENT OF SUSTAINABLE BIOMASS THROUGH FOREST RESTORATION

(WBS #: 4.1.1.52)

Recipient:	Pacific Northwest National Laboratory
Principal Investigator:	Mark Wigmosta
Project Dates:	10/1/2016–9/30/2019
Project Category:	New
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$0
DOE Funding FY 2015:	$0
DOE Funding FY 2016:	$0
DOE Funding FY 2017:	$220,000

Project Description

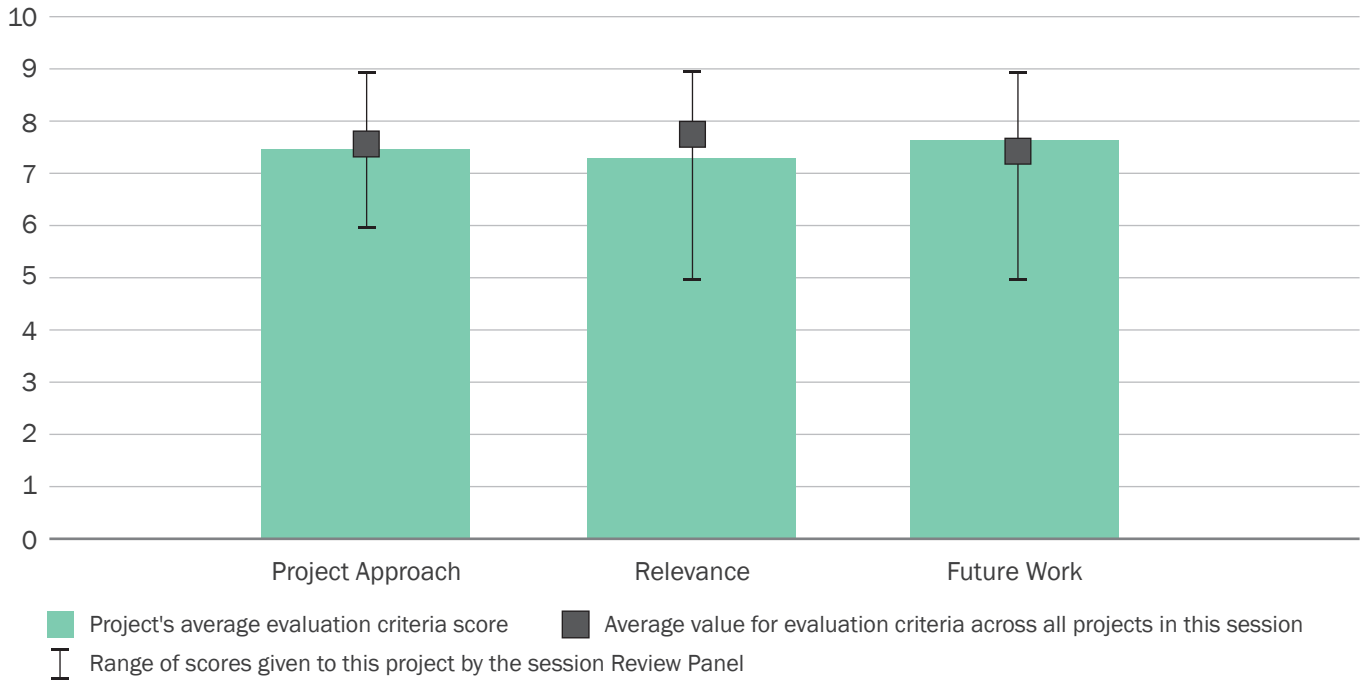
Sustainable biomass from forest restoration to reduce high fuel loads and fire risk is a potentially significant source of bioenergy with numerous potential benefits including increased ecosystem services such as improved flow regimes for aquatic habitat. A multi-agency collaboration between DOE and U.S. Forest Service (USFS) will use high-resolution spatial vegetation characteristics data to develop accurate estimates of sustainable forest biomass along with distributed hydrological, ecological, and wildfire risk modeling in a multi-objective analysis framework to assess the extent of forest thinning activities that restore landscape function to reduce high fuel loads while increasing biomass yield and stream flow in a publicly and ecologically acceptable manner. We will initially focus on high-fire risk areas in the Pacific Northwest at the sub-basin to regional scale using data, models, and analysis techniques that can be applied nationally.

Overall Impressions

- This project seeks to address an interesting and developing issue. Previous fire suppression policies in the United States have led to dense forests and heavy undergrowth. Having traveled frequently in

Weighted Project Score: 7.5

Weighting: Approach–25%; Relevance–25%; Future Work–50%.



the West, I have seen what happens when a fire gets out of control. This project seeks to develop and demonstrate an analysis framework to prioritize how and where to target forest restoration practices such as timber harvesting and thinning. Such a project would benefit the growing bioeconomy by making large volumes of forest residues and small-diameter trees available for bioenergy while reducing wildfire risk, increasing water yield, and improving ecosystem services. While new, the project appears to have good management practices in place and is a collaboration between various partners. Of interest to me was the fact that increased forest density not only increases fire risks but impacts hydrologic processes such as stream flow patterns and reduced water availability. This project will utilize a linked set of spatial, biophysical models coupled with existing decision support software to identify high fire risk locations for restoration that have sufficient biomass and the potential to increase peak snowpack duration to improve summer flows critical to fisheries. So, if successful, this project will increase forest-derived biomass availability for the bioenergy industry while improving water flow and aquatic habitat.

In addition to completing the resource database and decision analysis tools, an important milestone will be selecting a demonstration basin for detailed analysis. It will be important to engage outside stakeholders to determine what forest restoration scenarios would be viable. It may be necessary to look at road access, for example, or slope conditions. Whatever forest restoration scenario is proposed, it must be economical and sustainable. In some cases, it may make sense to burn the biomass in place since harvesting it would not be cost-effective. I would urge working with USFS on this. Also, have you clearly defined what sustainability metrics or ecological services will be looked at beyond hydrology? Policy may also play a role here, so looking at various policy interventions could be useful. For example, would the information developed here also apply to national parks?

- This is an interesting project with potential relevance to multiple resource management objectives across multiple stakeholders. I challenge the team to more clearly state how they will coordinate analysis with existing efforts and how they will ensure that outcomes of the project are communicated to critical stakeholders and/or user groups.
- The project argues that there would be substantial ecological and, potentially, hydrological benefits to removing potential fuel from forest areas and using it in biofuel production. Those benefits would, however, arise from any program to reduce fuel accumulation including, presumably, prescribed burning and/or curtailing routine fire suppression programs. It's not at all clear that gathering such materials for use in bioenergy production would be economically feasible. This should be addressed before the project continues, at least under BETO's auspices.
- It does seem profitable to look at forest residue as a feedstock in a sustainability context; however, I don't think that this is where BETO can have its biggest impact on sustainability.
- The project seeks to develop a decision support to help prioritize where to target forest restoration efforts via strategic thinning and prescribed burning, based on benefits for biomass production as well as ecosystem services. The potential use of biomass from forest restoration activities is a potentially important biomass supply pathway and this project will help assess the environmental trade-offs and maximize benefits from societal activities. Presumably, incorporating biomass adds a financial benefit to the forest interventions or possibly reduces the GHG impacts of traditional practices by reducing fire risk and putting the residues to use. It would be useful to quantify these benefits and incorporate the logistics and potential demand for biomass for energy to be able to characterize the potential "win-win-win" opportunities.

  The project's goal could also focus more squarely on developing a practical tool for decision making. This will require more explicit discussion of user

needs and decision-making processes and how the tool can provide actionable information.

- The project is well organized and roles are well defined.

  The project team represents appropriate skills to accomplish the objectives.

  The metrics of success are appropriate and simple enough to maintain focus. Moving forward, it will be helpful to use these metrics to track project progress.

  Data management is a key challenge for this project. As the project collects data, it would be beneficial to provide that data in a manner suitable for incorporation in future work by this project team or others.

  It would be helpful to engage stakeholders including those representing fire management, forest conservation, and the forest products industry.

PI Response to Reviewer Comments

- We thank the reviewers for their valuable comments. Our project is designed using models, data, and decision support software that can be applied to a range of conditions on public and private forest land across the United States. To be effective in fire risk reduction and economic sustainability, restoration efforts will include significant commercial timber harvest with biomass for energy derived from tree tops and branches, along with non-merchantable small diameter trees. Multi-criteria suitability analysis, including fire risk, topographic landform, slope, aspect, vegetation type, protected areas, and critical channel habitat will be used to initially select potential restoration areas. Local conditions such as slope and existing road access will determine the appropriate method and costs of harvest and the volume of biomass available for energy. In some cases, economics may require some logging residue be burned in place, rather than collected for bioenergy.

  This project will use the USFS Forest Inventory and Analysis (FIA) BioSum analysis tool to ensure proposed restoration scenarios that include bioenergy are economically viable. BioSum incorporates a transportation cost model, a treatment cost accounting module, a log valuation model, and a crown fire hazard evaluator with FIA plot data. The model will be used to evaluate costs associated with biomass energy production under alternative restoration scenarios, and compute haul costs to alternative sites at which forest biomass-based energy production facilities could be constructed. BioSum has been used to support biomass plant capacity decisions in Lakeview, Oregon; forest practices policy development by the California Department of Forestry and Fire; and regional analysis of opportunities to attract bioenergy investment capital in New Mexico.

  We will utilize the Ecosystem Management Decision Support (EMDS) software in the trade-off analysis and decision-making process. EMDS is the USFS corporate software solution for decision support used by the USFS and U.S. Department of the Interior since 2006 to evaluate wildfire potential across the continental United States and establish priorities for allocating fuel-treatment budgets. Beginning in 2007, this was expanded to include the U.S. Department of the Interior Fish and Wildlife Service, Bureau of Indian Affairs, National Park Service, and Bureau of Land Management. Co-Investigator, Dr. Reynolds has 25 years of experience in development and application of decision support systems, including 21 years as architect and project lead of EMDS. USFS Co-I's Hessburg and Reynolds are the two principal architects of the Okanogan Wenatchee National Forest landscape restoration decision support tool based on EMDS.

  EMDS implements a framework to support the functions of a spatially-enabled decision support system that helps decision makers rationally evaluate strategies or solutions for spatial or geographic

problems. These are often complex problems with large datasets, include a high degree of uncertainty, and entail multiple stakeholders with conflicting interests and viewpoints. EMDS is often used to evaluate, compare, and prioritize scenarios or alternatives.

Once our demonstration basin is selected, we will conduct workshops with end users and subject matter experts concerning resources and conditions that must be managed, know how treatments will be applied, and what decisions are needed. We feel that the role of decision support is not to deliver the answer, but to organize and present information in a way that facilitates informed deliberations among decision makers including those that represent fire management, forest conservation, and the forest products industry. Successful application requires a high level of involvement of senior managers, policy experts, technical specialists, and scientists. The proper planning for a decision environment will enable the building of tools that meet user needs in a direct and efficient manner.

SYSTEMS ANALYSIS AND MODELING

(WBS #: 4.1.2.1)

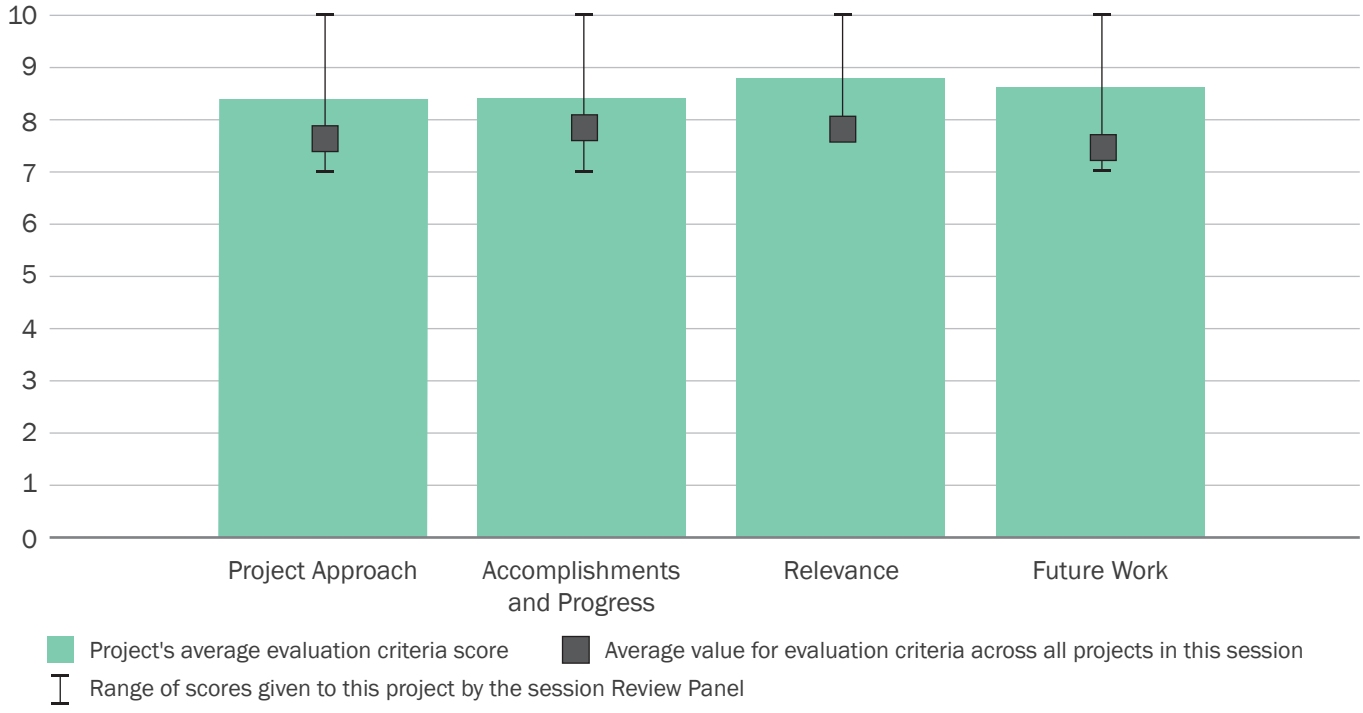
Recipient:	National Renewable Energy Laboratory
Principal Investigator:	Amy Schwab
Project Dates:	10/1/2010–9/30/2017
Project Category:	Ongoing
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$1,272,000
DOE Funding FY 2015:	$1,400,000
DOE Funding FY 2016:	$1,310,000
DOE Funding FY 2017:	$1,300,000

Project Description

BSM is a unique, validated, state-of-the-art, fourth-generation model of the domestic biofuels supply chain which explicitly focuses on how and under what conditions biofuel technologies might be deployed to contribute to the U.S. transportation energy sector. BSM examines the implications of policies and incentives as well as their potential side effects; uses a system dynamics simulation to model dynamic interactions and transitions across the supply chain; and tracks the deployment of biofuels given industrial learning and the reaction of the investment community in the context of land availability, the competing oil market, consumer demand for biofuels, and government policies over time. Under expected market conditions, scenario analysis based on BSM shows that the biofuels industry tends not to rapidly thrive without significant external actions in the early years. Interventions that lead to operation of pre-commercial and commercial facilities have been identified as having strong influence in starting the growth of a commercial biofuel industry. Policies which are coordinated across the whole supply chain in BSM foster the growth of the biofuels industry and production of tens of billions of gallons of biofuels may occur under sufficiently favorable conditions.

Weighted Project Score: 8.6

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



Overall Impressions

- BSM is a system dynamics model of the domestic biofuels supply chain designed to inform stakeholders, management, and policymakers of the implications of policy choices and the impacts of various biomass-to-biofuels scenarios. The model offers the unique opportunity to stimulate discussion and shape thinking across the entire biofuel value chain. The team members have increased collaboration with BETO and other national laboratories as well as outside stakeholders since the last review. This effort is appreciated as is its transparency and careful attention to detail. The team continues to perform impactful analyses designed to inform DOE. One such study looked at the future potential of aviation biofuels. The analysis suggested that six billion gallons of aviation biofuel is possible by 2030.

  The team is exploring scenarios of biofuels penetration in marine applications as well. Its work since the last review has included the development of a user-friendly visualization platform for the BSM. This will be especially useful when the model is released publicly later this year. Because the model is intended to inform decision makers it will be important to get the model into the hands of policy and decision makers. Making the model accessible to the public will be a good start. However, the team will need to carefully consider the rollout strategy as its time could quickly get consumed with supporting the training and troubleshooting of other users. Future work will include performing relative analyses in support DOE and BETO goals as well as continuing the development of advanced statistics and visualization capabilities. While the team is not specific as to what relevant topics it will address in the future, I would suggest that adding biobased chemicals and products to the model would be useful as these materials are enablers of the bioeconomy with many early examples such as bio-succinic acid already in commercial production. Adding the various algal production pathways would also be beneficial.

- In many ways, a model presentation and a model for project management and implementation. Attention to internal model development, technical approach, and quality assurance/quality control are commendable, as is attention to use of the ultimate product and how it can help a wide variety of stakeholders.

- The strength of systems dynamics modeling is to develop scenarios based on plausible interpretations of current circumstances. The weakness is that out-of-sample, as it were, behavior can be driven to implausible extremes. In contrast to economic models (which, to be fair, rely on their own sets of dubious assumptions and have their own weaknesses), there is not necessarily a set of self-correcting behavioral assumptions built in. I've noted elsewhere in remarks on other projects that systems dynamics models need not conform to "Kahn's Law:" "If something can't go on forever, then it won't." My sense, though, is that the BETO research portfolio is strengthened by drawing from a wide range of approaches, and so models like this should be supported so long as they're useful, albeit with (as, again, for any approach) an appreciation of their weaknesses.

- This is a powerful and flexible addition to the BETO toolbox for analyzing a variety of biofuel pathway development scenarios and policies. The project has already made progress on very policy relevant and timely issues, such as international aviation.

  It would be valuable to more clearly articulate the strengths and weaknesses of the systems analysis approach. Also, the focus seems to be on production volumes and timing of deployment. It would be important to also ensure that the scenario modeling provides transparent information on the economics, particularly the costs and economic benefits to the

government and private actors. There is also a focus on financial supports for different parts of the industry. It would be important to transparently communicate to what extent these supports are required over time or are temporary measures to kick-start industry development. It also seems important to include consideration of environmental sustainability metrics as outputs of the modeling, as well as associated sensitivity analysis to key parameters, scenarios, and assumptions. It would also be valuable to ensure that scenarios can be analyzed that match current policy discussions.

Finally, the focus on visualization for stakeholders is commendable. The virtual/augmented reality component is also very interesting and innovative, but it would be important to carefully analyze the needs of stakeholders and value added to appropriately balance investment across model development and more sophisticated visualization.

- This is an important part of the BETO A&S portfolio and stands out as a high performer amongst projects in the portfolio. Moving forward the project should continue its collaborative stance with other DOE laboratories and researchers outside the DOE community. EPA and USDA are important stakeholders for this work, it would be appropriate to consider how these relationships could be established more firmly in terms of data flows between research groups and the use of the BSM to answer questions of interest for EPA and USDA policymaking.

PI Response to Reviewer Comments

We greatly appreciate the helpful recommendations made by the reviewers. Indeed, we will be doing an analysis on biomass-based chemicals and bioproducts in FY 2017 and we have plans to expand analysis into other areas such as marine, heavy duty vehicles, and feedstock exports. The BSM already incorporates algal pathways, as is shown in the supplemental material. We recognize that a public model rollout can be very time consuming. In response, we are engaging with an initial alpha testing group of BSM users prior to release in order to gain a better understanding of different use cases and the best approach for supporting a new user community. With the BSM release, we plan to continue our emphasis on collaboration. We appreciate the suggestion that USDA and EPA are important stakeholders, value our existing relationships within those organizations, and will endeavor to create tighter coordination with them by reaching out to additional organizational units, seeking more direct, extensive, and timely data flow, and exploring analytic opportunities. We also value collaborations with those outside of federal agencies--such as state agencies, industry, and academia--and will continue to seek out opportunities to collaborate with them.

We are aware of the potential value as well as the potential drawbacks of the system dynamics (SD) methodology. Similarly, we are cognizant of the strengths and weaknesses of the methodologies used to form the input data used in the BSM. We have critically and conscientiously addressed those via module-by-module validation, sensitivity analysis, and carefully designed modeling experiments. Where possible, this entails calibration to empirical data. The resulting level of structural detail provides balance in feedback loops where simpler formulations might not, overcoming one of the potential challenges of SD. In general, we only report insights and conclusions that are robust with respect to the quality of the input data and the structural uncertainties in the BSM and that precisely qualify analytic results by stating under which conditions they hold and under which conditions they would be contradicted. One of the strengths of SD its considerable potential to generate multiple system behaviors across different input variable regimes that may offer nuanced answers to hypotheses.

The large variance-based sensitivity analysis of the BSM tackles many questions around policy cost and effectiveness including variations in policy type, magnitude, and duration. We plan to publish multiple journal articles on this analysis and anticipate that they will address comments around policy design and cost. We appreciate the reviewer's interest in NREL's advanced visualization capabilities that are utilized by the BSM. We will be careful to balance visualization techniques with the needs of stakeholders and prioritize resources accordingly.

ECONOMIC ANALYSIS OF RISK

(WBS #: 4.1.2.20)

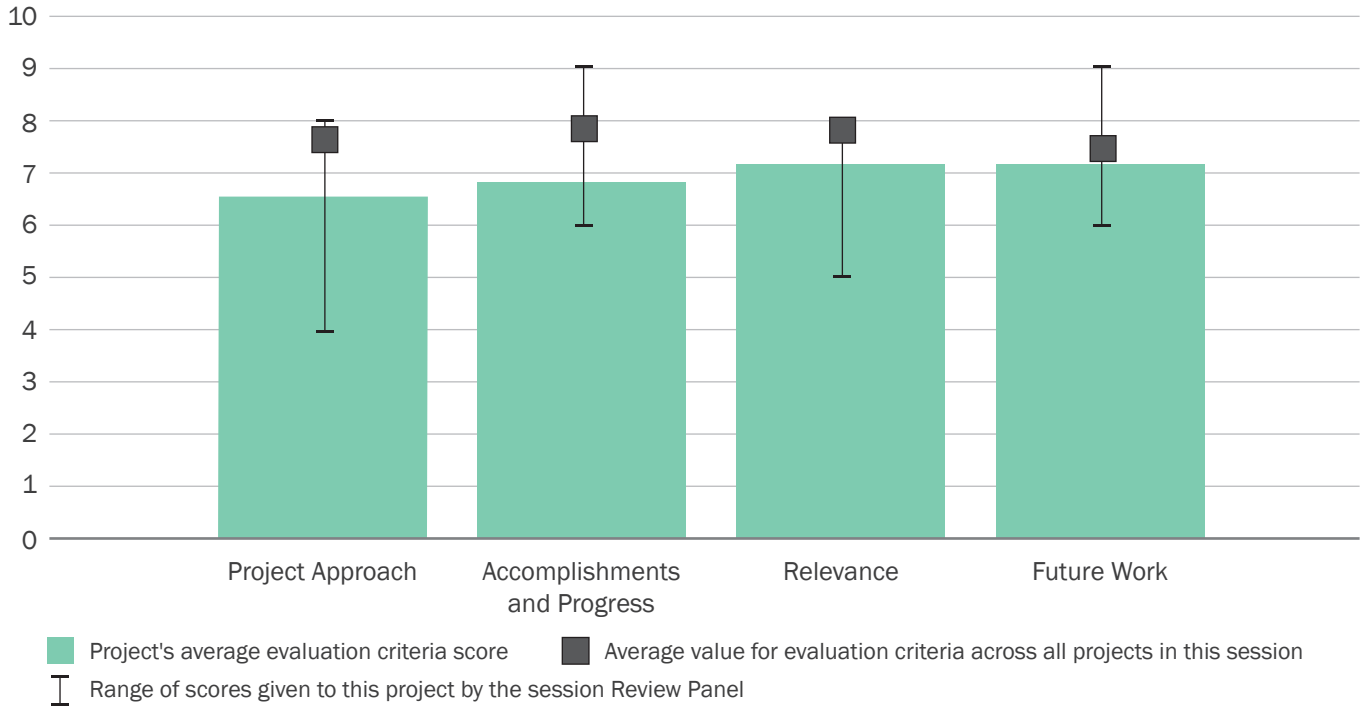
Recipient:	Idaho National Laboratory
Principal Investigator:	Jason Hansen
Project Dates:	10/1/2013–10/31/2018
Project Category:	Ongoing
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$250,000
DOE Funding FY 2015:	$150,000
DOE Funding FY 2016:	$250,000
DOE Funding FY 2017:	$570,047

Project Description

Inconsistent methods for analyzing risks in the feedstock supply chain lead to high financing costs, which is an investment barrier. The purpose of this research is to create a method investors can rely on to evaluate and price risks in supply chain projects based on industry collaboration. The work establishes standards and protocols for assessing risks in project investment from across the supply chain. The challenge is to ensure that the standards and methods are consistent with industry best practices so that investors, developers, insurers, and other financial stakeholders can be confident in project risk assessment. Researchers develop a framework to categorize, track, and assess overall feedstock supply chain risk in a project and build a stochastic techno economic model to quantify logistics cost risk in the supply chain. Applying the model, researchers have quantified uncertainty in a unit operation within the supply chain and translated it to a logistics cost to assess risk. Then, for a supply chain design, researchers identified the impact of uncertainty in feedstock quantity and quality on biofuel prices. This work supports BETO's mission of commercial viability in bioenergy, and its crosscutting goal for metrics and methods for understanding risks. Most importantly, the project creates a better, consistent method for analyzing risks, which supports breaking down the investment barrier.

Weighted Project Score: 6.9

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



Overall Impressions

- Today, a consistent method for comparing and pricing risk across project options in the biomass supply chain does not exist. This creates a barrier to investment. This project seeks to create a method to systematically analyze, measure, and compare risks in a way that is consistent with best practices so that investors can evaluate project risks. One of the strengths of the project is its close ties to the financial sector. While the management approach was not clearly defined, the team's desire to produce transparent, reproducible results is noteworthy. While this (renamed and refocused) project has just recently gotten underway, the team has begun to look at the primary cost and uncertainty drivers in preprocessing based on cost and equipment type. They have also completed work on developing a model to quantify the impact of uncertainty in the biomass supply chain of the minimum fuel selling price in the conventional supply system. It will be interesting to see how the work develops as it moves forward. The project's relevance comes from its efforts to overcome barriers in financing, thereby, enabling the development of commercially viable bioenergy and bioproducts production facilities. It closely leverages expertise in the financial sector to guide the evaluation methodology for consistency with the finance industry's best practices. If successful, this project could help move projects forward and accelerate the build out of the bioeconomy.

  The project is divided into two tasks. The first is to develop a framework to assess and integrate diverse risks and the second is to develop a stochastic techno-economic model to quantify the cost risk. While I understand the focus on standardizing risk in the biomass supply chain, this is not the only risk these first-of–a-kind plants encounter. Why limit this to the feedstock supply? Why not look at biorefinery risk as well? Also, the project plans to use stochastic techno-economic modeling to quantify cost risk. But what about technology and market risks? Policy risks could also play a significant role and should be added to the analysis even if they are limited to the field to biorefinery portion. Because some risks are more qualitative than quantitative, it will be difficult to come up with an overall risk. Some method for weighting will be required and, since weighting is always subjective, will vary from person to person. How does the project plan to overcome this obstacle?

- The project's two tasks seem to be a reasonable approach to address the stated project objectives, addressing both a stated need for an evaluative framework and the development of a tool for addressing one critical portion of supply chain risk. I also appreciated the discussion of general contingencies for project developments (e.g., adjustment of framework based on feedback). In future work, I challenge the project team to provide greater detail on stakeholder outreach given the critical nature of buy-in and adoption of the project's resulting standards and certification framework.

- There are a number of sources of uncertainty and the success of this project will ultimately depend on whether the researchers are able to address enough of those sources to inform decision- and policy-making usefully. A critical distinction is between "garden variety" uncertainty (e.g., what is the outcome going to be?) and somewhat more esoteric notions. Not knowing what's going to happen is not necessarily a source of a market failure that will prevent investment that ought otherwise to occur. What is more problematic is when one party knows more than another (e.g., the "asymmetric information problem") or when no one knows the probability density function (sometimes called "Knightian uncertainty"). The project will be most useful if it can address these problems by expanding its focus to a wider array of risks (e.g., climate, market, and policy), as well as thinking about how technical (ex-

tent of market) and institutional (forms of contract) considerations might mitigate them.

- This project outlines a substantial amount of future work. There is a lot to be learned but it isn't clear that data are or will become available to support these modeling efforts.
- The project seeks to address financing barriers to biomass production by developing a framework for quantitatively assessing biomass supply chain investment risks. The project is targeting BETO's goal of aiding the commercial development of bioenergy pathways by catalyzing investments in biomass supply chains by facilitating risk assessment. This is an innovative and very practical, targeted undertaking. Given this clear focus, however, to maximize chances of success, stakeholder outreach to the targeted financial sector audience is essential to determine if the quantification of these risks will truly unlock supply chain investments, as well as to determine what type of analysis will be most helpful.

  From a technical standpoint, it would be helpful if the project developed a fuller list and categorization of the relevant risks and uncertainties, mapped out to who bears the risk and in what context, as well as a discussion of which are unique to biomass versus other agricultural supply chain investments. Also, to the extent there are important risks not addressed by the project, such as biomass policy developments, for example, these should be identified and potentially alternative scenarios considered. Finally, it is important to know which risks are correlated or uncorrelated over space and over time. This would allow diversification over a portfolio of investments as well as understand opportunities for learning and adjustment over time.
- This project addresses the issue of improving understanding of investment risk associated with biofuel systems through creating supply chain risk estimates using distributions for key parameters and Monte Carlo Analysis. The project is engaging finance industry stakeholders to help ensure its relevance.

  The presentation does not make clear the interaction with the other groups working on TEA and LCA. The flow of data across DOE-funded projects should be made clear. Where is this project performing new TEA and where is it incorporating information already available? Where is it building on existing TEA studies? How are incorporating environmental and policy risks associated with biofuels? How is it incorporating uncertainty in global market conditions? Will the effects of developments in other energy technologies be considered?

  The scope of this project, from feedstock production through to intake at the refinery is only part of the scope that would be considered in an investment decision. It would be helpful to connect with other TEA to provide a more complete picture of the overall costs and risks associated with biofuel pathways. While the scope of this project is limited to biofuel feedstock logistics, it would be helpful to frame results using the work of others to characterize other portions of the full biofuel life cycle cost.

  There is a disconnect between the content of the presentation which would indicate the project is in the initial stages while the quad chart states it is 35% complete. If the project is 35% complete, the results are not well presented in the PPT slides.

  Because the intent is to influence the financial industry, the project metrics for success should include critical feedback from the finance industry and examples of how the metrics/results calculated here are being used by finance industry stakeholders.

  The benefit of this project is that it would "grease the wheels" of investment in bioenergy systems. This is relevant, but it should be carefully considered whether the state of biofuel technologies is such that this is the most significant question to be addressed. For example, if the project is providing

information for systems that are on the verge of commercial viability and it stimulates investment, it would be well worthwhile. However, if the systems analyzed are not ready for investment or if further TEA and LCA reveal other systems to be preferable to those considered here, the effort would not be very impactful.

The goal of creating a metric for biofuel investment risk is a good one and could really move the field forward. The presentation did not provide details on how this would be accomplished. Calculating risks for biofuel systems is a good first step, but there is much more work to be done to get consensus around an index and to engage stakeholders who would produce the data for the metric moving forward and others who would use it in investment decisions.

The case for the project would be stronger if Ecostrat or Stern Brothers were sharing in the project cost.

The future work for this project should include effort devoted to engaging additional stakeholders, establishing a project steering committee that periodically reviews project progress, next steps, and future plans, and establishing connections with other research groups in BETO and national laboratories, USDA, and EPA with the goal of taking advantage of results of other studies and feeding into ongoing/planned work elsewhere.

PI Response to Reviewer Comments

- Extend risk standards and certification framework beyond feedstocks into conversion. An overarching theme emerges from the reviewer comments; the risk standards and certification framework is as important to conversion as it is to feedstocks and should therefore be extended to conversion. Project researchers agree with this and recognize the need to extend the framework to conversion. However, the focus of the effort is deliberately on feedstocks because of the barrier that risk in feedstock present to the emerging biofuels industry. Lack of clarity about the level of risk in biomass supply is a key factor limiting the scale and pace of bioenergy project development in the United States. The lack of tools and methodologies for quantifying biomass supply chain risk means that capital providers in the North American investment communities either overprice or underprice biomass project risk or refuse to price it at all. The result is that bioenergy project risk ratings tend to be high (many are pushed in to junk bond ratings territory), which makes most projects difficult or impossible to finance. The bottom line is that only a very small fraction of bioenergy projects that are proposed bioenergy projects are actually built. While concerns about technology, construction, and offtake have clear paths to resolution, at the present time there is no established way to quantify, discuss, and understand biomass supply chain risk.

  As it pertains to biomass feedstocks, the industry is in its infancy. That is to say, while the means of evaluating the risks for technology, construction, and offtake are well established and understood, the risks around biomass supply chains are not. It is precisely this lack of clarity that has stopped many bioenergy projects that would otherwise be built and running today. Stern Brothers and Co., the nation's leading investment bank facilitating project financing for the renewable energy industry, confirms that this is a key challenge inhibiting bioenergy industry expansion. The bank's clientele includes many of the advanced biofuel production companies who have applied for and secured commitments for guaranteed loans from USDA for commercial plant build-out in the last two years including: ZeaChem Inc., Chemtex International, Fulcrum Bioenergy, Enerkem Inc., and Fiberight LLC. Less unknowns exist for conversion than for feedstocks. Conversion technology and biorefinery operational risk is not unlike other chemical processing facilities.

Researchers acknowledge operational risks as an important area for analysis and maintain it as an area for future research.

Deploy risk standards and certification framework into the marketplace. The reviewer comments underscore the importance for project researchers to engage with industry and deploy the framework into the marketplace. Project researchers concur with this recommendation-- the project plan calls for significant industry engagement including partnering, advising, and collaboration. Ecostrat, a project partner and significant cost share contributor, has been involved in many renewable energy projects, assessing project financing, risk, and conducting other analyses. Ecostrat collaborator Stern Brothers and Co. has joined the project as a partner, too. Leveraging these partners and other contacts in industry risk assessment, project researchers have created an Advisory Board to guide project development consistent with financial sector best practices. As the project matures, engagement with stakeholders in industry and the financial sector will continue to increase.

Project researchers are keen to keep in close touch with marketplace stakeholders so that analysts and others in industry and the financial sector will have confidence to use the risk standards and certification framework.

BIOPRODUCTS TRANSITION SYSTEM DYNAMICS

(WBS #: 4.1.2.31)

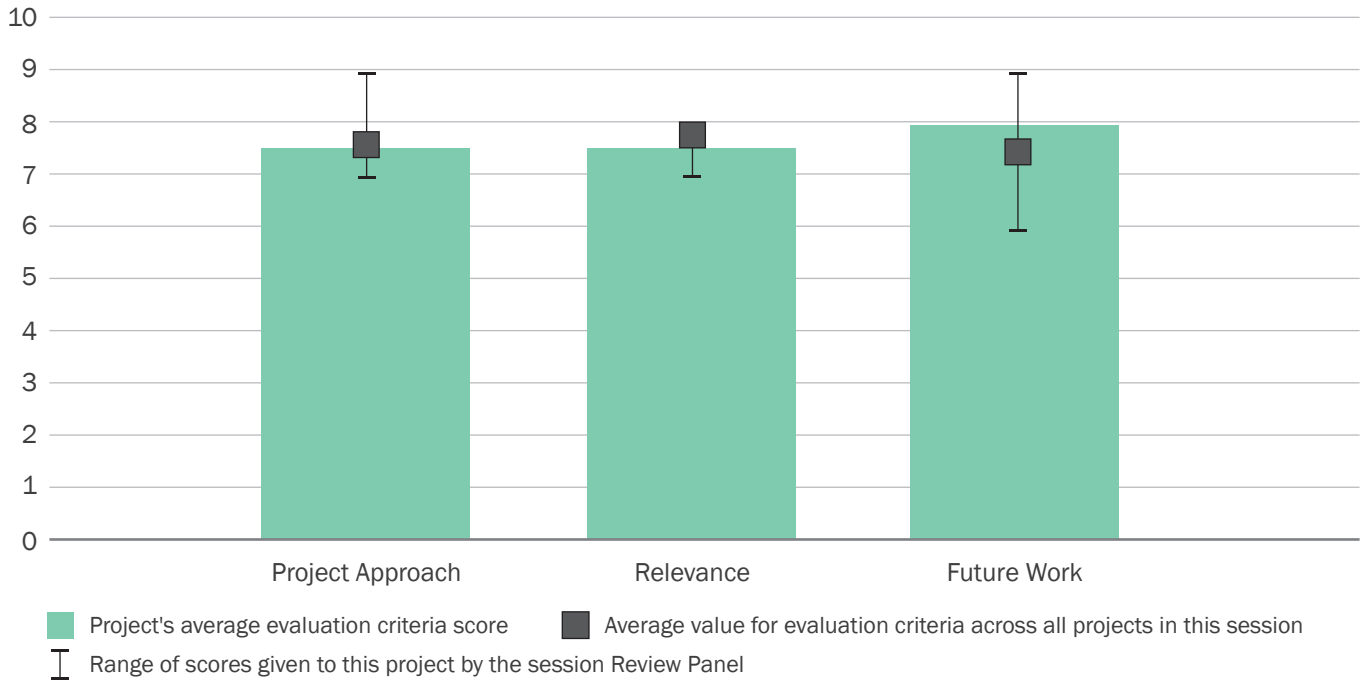
Project Description

The Bioproducts Transition System Dynamics project uses data and expertise from BETO-funded tasks to develop an analysis capability that enables a deeper understanding of early-market transition dynamics in the bioproducts industry. We will develop a transparent, analytic system dynamics model that tracks transition dynamics for several chemicals from biomass that satisfy either niche or scalable markets that are developed through economic and/or policy-driven mechanisms. The project will explore the influence of investor decision making, techno-economics, and market factors on these dynamics and will capture the role of investors and R&D dynamics in overcoming barriers. It will also explore the conditions under which synergies between bioproducts and biofuels can both assist biofuels and enable a more robust transition to a bioeconomy. Key questions to be answered include how investor decision-making interacts with market and other factors to impact the bioproducts industry development, the extent to which such factors and development are predictable, and how data and knowledge gaps impact the results. Our goal is to demonstrate the analysis approach, provide insight into the bioproducts industry, and identify gaps in understanding, with an initial focus on bio-

Recipient:	National Renewable Energy Laboratory
Principal Investigator:	Mary Biddy
Project Dates:	10/1/2016–9/31/2017
Project Category:	New
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$0
DOE Funding FY 2015:	$0
DOE Funding FY 2016:	$0
DOE Funding FY 2017:	$200,000

Weighted Project Score: 7.8

Weighting: Approach–25%; Relevance–25%; Future Work–50%.



products with existing markets. Work in out years will focus on further engagement with industry and other stakeholders to evaluate bioproducts which have not yet entered the marketplace.

Overall Impressions

- BETO is interested in developing a broad understanding of conversion processes that produce bioproducts and possible scenarios for successfully advancing the bioproducts and biofuels industries. Therefore, this project seeks to develop an analysis tool capable of understanding the drivers that impact the growth of the bioproducts industry. This project builds on existing BETO work and connecting with other established BETO models will be important. Not only is it important to make sure that this project uses the data produced by other projects but that the information generated in this project can be, in turn, used to further other BETO work as well. The project appears to be well managed with frequent communication, clearly defined goals, and achievable milestones. It is great to see that collaboration and integration of data from ongoing projects as well as interaction with key stakeholders are part of the management approach. However, there are several projects working in closely related aspects of this work. Care should be taken not to duplicate efforts. This work will lay the foundation for exploring possible future scenarios and the connections between bioproducts and biofuels using a transparent SD model in an effort to better understand the technical and market synergies with biofuels. The emphasis will be on creating a flexible SD modeling framework to analyze the behavior of complex real world feedback systems over time. This is not easy and careful validation of the model will be needed. If successful, the project should provide critical insights and deep understanding of the complex factors involved in bioproducts production and market introduction as well as inform strategies and policies.

  The team has outlined future work including developing the model and have already chosen six biobased chemicals for initial study based on several characteristics. One potential challenge with a project of this size is the ability to identify a few selective materials to begin the work that are representative of the sector as a whole. Having enough information available is critical, but these materials should also be broadly relevant to the overall work. I would suggest, in addition to the materials already down-selected, to focus on intermediates that could be further processed into a suite of products as well as platform chemicals that can be further upgraded for multiple high-value uses. It will also be necessary to focus on bioproducts that can be produced cost competitively with their fossil counterparts. It has been my experience that there is no real green premium. This also gets to the question of drop-in applications and materials with enhanced functionality. Drop-ins have an advantage when it comes to certification and validation in existing applications. However, enhance functionality provides value which can often offset increased cost. It is also important to consider the end users when looking at risk and competitive scale. Because this is an evolving market, technology breakthroughs in one area could positively impact the production of bioproducts elsewhere. For example, developments in shared feedstock handling could facilitate developments in other systems. Finally, this work appears to be policy oriented. Are there policies such as innovation incentives that could rapidly move this space forward?

- My only reservation is one of potential duplication with other efforts in the BETO portfolio. Responses from the presenter were helpful in acknowledging that crossover and/or synergies were recognized. Some level of system redundancy is helpful, so this is not a lingering concern of mine.

- My concerns with the project have largely to do with the limitations of SD as a method. Results depend on the specification of the equations driving them and it's not entirely clear to me what the empirical and/or logical basis for such specifications is. One must be careful not to extrapolate relationships which are reasonable approximations to local dynamics to the point where they generate a reduction ad absurdum. It is not clear to me how the calibration of the modeling effort here will avoid such a possibility.
- This project addresses an important question of how bioenergy and bioproducts markets are likely to evolve in their early stages. Nevertheless, the verdict is out on how useful this SD modeling approach can be. It will be important to ensure the model draws on data from other projects as much as possible and also to prioritize the stakeholder engagement component. This can perhaps be one of the most valuable parts of the exercise including perhaps conducting some detailed case studies that can provide qualitative insights alongside the quantitative analysis.

  This seems like an interesting, flexible and potentially powerful addition to the toolbox for analyzing strategic policy and investment questions on bioproduct and biofuel development. If successful, the model could be applied to a range of other questions. The verdict is still out on the insights that can be derived, but the interactions with stakeholders should be fruitful. It will be important to focus on the most actionable questions where the model can truly be used to test hypotheses, rather than build in the answer with an assumed structure or parameters.
- This is an exploratory project with a strong team, well developed project plan, clear go/no go criteria, and a good chance of success. Moving forward, it would be helpful to more clearly articulate how the results will be used by stakeholders and to define what data will be developed as inputs to this project and how they could be disseminated in order to add value in their own right.

PI Response to Reviewer Comments

- We appreciate the numerous helpful comments that the reviewers offered, and are grateful to the reviewers for their time, consideration, and support. This project strives to fill a current gap in the BETO modeling portfolio that is not being addressed in other projects. Specifically, the model seeks to develop a more thorough understanding of the investment decision-making process for early-stage bioproducts. This is being informed through learnings from stakeholder interviews, which have focused on the key components of the investment decision-making process and how they may be weighted differently for different products. Being able to model this process will enable great insights into, for example, where to focus policy and/or funding to achieve the greatest benefits to the emerging bioeconomy. This tool will help BETO better understand commercialization potential of products and could help alignment of R&D strategies and funds by BETO to support technologies with a higher probability to move to the market faster and grow the bioeconomy at a greater rate.

  Even if data are unavailable, the insights gained from stakeholder interviews and exploring the interdependencies in the system will be valuable particularly as the industry evolves and more data become available. During future work, we plan to increase the different types of chemicals that will be explored including functional replacements, intermediates, and chemicals cost competitive with petroleum products. Some of these components will be explored in FY 2017. The set of biobased chemicals chosen for study are all intermediates, and include both functional and direct replacements for fossil-based chemicals. This type of exploration will illuminate the varying market structures

for these chemicals and help stakeholders examine investment strategies. We will also expand to look at potential leverage points such as policy, prices, or other investment drivers. These leverage points can be readily identified and compared through the proposed sensitivity analysis. For policymakers, these insights could point to areas where they should focus resources. For industry, these insights could help to identify opportunities for their business cases.

The SD modeling framework has proven its value over the last decade of its application to scenario analysis of the biomass-to-biofuel supply chain. We are acutely aware of the dangers of extrapolation, so the project has undertaken a calibration and confidence-building effort to model a historic success and failure in the bioproducts industry, thus moving the future use of the model from the realm of extrapolation to that of safer interpolation. Additionally, the specification of SD equations and feedbacks will be reviewed by subject matter experts and modelers with expertise in SD and other frameworks.

We will continue coordination with existing BETO projects and participation in the Bioproducts Working Group to keep abreast of developments and to avoid any duplication of modeling efforts. In addition, we will continue to engage industry through one-on-one conversations and a planned workshop to gain their feedback on the direction of this research and their insights about the investment decision-making process.

LAND USE CHANGE DATA AND ANALYSIS

(WBS #: 4.1.2.40)

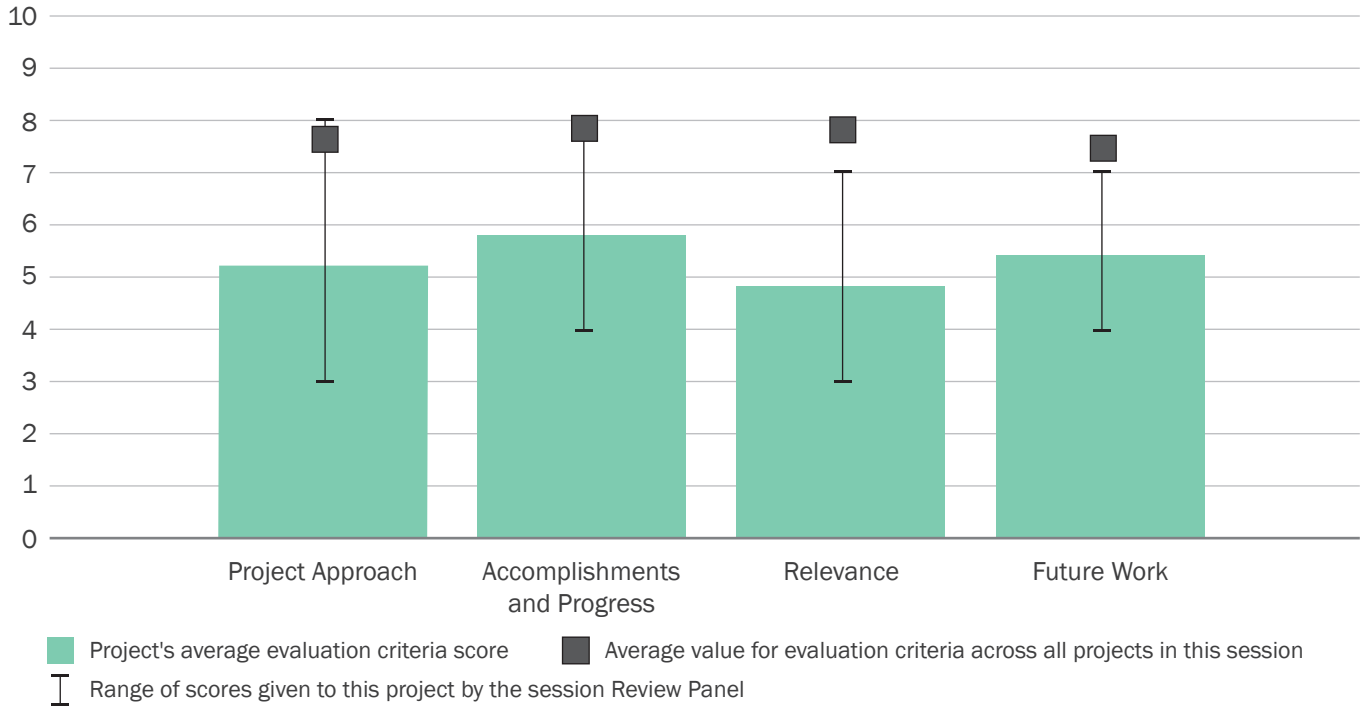
Project Description

Recipient:	Oak Ridge National Laboratory
Principal Investigator:	Nagendra Singh
Project Dates:	10/1/2010–9/30/2017
Project Category:	Ongoing
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$200,000
DOE Funding FY 2015:	$150,000
DOE Funding FY 2016:	$225,000
DOE Funding FY 2017:	$225,000

The objective of this project is to develop a novel land cover change detection method, which can be used to rapidly estimate changes in land cover using very high temporal resolution (8–16 days) satellite data. LUC is dynamic in nature which cannot be captured by static datasets and leads to erroneous conclusions when used for sustainability analysis. With recent advances in computing it is possible to analyze massive amounts of big data to extract information from high volumes of multi-temporal satellite imagery. This is especially critical for identifying changes in vegetation which has a natural phenology depending on location and climate and can be impacted by natural (e.g., hurricanes and drought) and man-made phenomenon (e.g., fire and LUC due to bioenergy). This project aims to provide tools and datasets to accurately assess changes in land use and land cover for which consistent and reliable datasets are lacking. The ultimate goal of this project is to integrate the models into a monitoring and visualization framework where changes in land cover over a long time period can be analyzed and visualized in near-real time. This will provide BETO, researchers, and policymakers the ability to accurately identify areas

Weighted Project Score: 5.3

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



undergoing changes in land cover, yield, and biomass for analysis, planning, and mitigation purposes.

Overall Impressions

- This project aims to provide a suite of tools and datasets to accurately assess and visualize changes in land use in near-real time. It does so by applying novel classification and change detection techniques to time series satellite data to understand and characterize changes in land cover and use. The project team has regular meetings to discuss issues, tracks quarterly deliverables, and submits quarterly progress reports. Greater collaboration and integration with other BETO projects should be encouraged. For example, can the data produced by this model be used to validate existing LUC models? The project's technical accomplishments have been the development of a semi-supervised model that works with limited ground truth data and the development of a change detection platform for estimating and visualizing changes. While these are great accomplishments, I am concerned about the ability of the tool to be able to distinguish between plant types such as hardwoods versus softwoods or between energy crops such as switchgrass and miscanthus. Today, the resolution is not fine enough to characterize subtle changes in plant types. In other cases, the model can detect a change, but there is no way to attribute that change to biofuels or understand the causal relationship. So even if the model detects a change, there is no way to understand why there is a change. For the model to truly be effective, it must be able to monitor and measure subtle changes with time over relatively large regions. Being able to measure changes in the way land is used over time is a worthy goal and has real impact on the growing bioeconomy. However, the current state of development falls short of the stated goals. In addition, the most critical issue is to step back and ask who is going to use this tool. Is there a customer for this work, and how does this work integrate with other BETO activities? The researchers need to clearly define the linkage between this work and who will use it if it is going to be useful.

  All projects, not just this one, should have a clear link to the end customer (not just BETO) to understand the value the project will bring. Future work includes developing a model to forecast the expected land cover value at any given time based on past observations and to integrate climate, yield, and acreage data and other socio-economic data in the system to better understand drivers of LUC and management. The presenter also commented that the team was looking at incorporating policy into the tool. It is hard to visualize how this would be accomplished. At this point, focusing on more specific near-term technical milestones may be appropriate.

- The presenter stated that the goal is not to assess effects of bioenergy policy, but that is explicitly listed in the project goals section of the presentation. This needs to be resolved to fairly evaluate how this project meets/fails to achieve project objectives. At present, the work is essentially creating an LUC monitoring and visualizing tool, which is an interesting but crowded space. Attributing change to any particular driver is where the real value of the project lies in my personal opinion, but this aspect was not described in sufficient detail to allow for evaluation.

- The main issue with this project is that it is not clear what its intended contribution is. I am certainly impressed with the data analysis capability described. At the same time, however, I'm not sure how, or possibly even if, this will be helpful in achieving the larger goals of BETO.

- This project is pioneering cutting edge approaches to LUC detection with remote sensed data and could yield very valuable data products for LUC analyses and monitoring related to bioenergy. However, a weakness is that the project does not appear well

integrated with potential user demands. Better understanding the needs of potential users and perhaps piloting a test application could help ensure maximal impact in the remaining stages of the project. Similarly, the project should ensure coordination and integration with other existing LUC detection efforts, such as at the University of Maryland and the Brazilian Space Agency where similar methods are being developed and applied.

- It would be helpful for this project to take a step back and identify the key questions it is answering, identify stakeholders for those questions, gather stakeholder feedback on the usefulness of the project (e.g., through holding a workshop on LUC tracking), map the relationship to other satellite image analysis efforts, and clearly articulate how this project addresses a salient problem in a way that other ongoing work cannot.

PI Response to Reviewer Comments

- This project is an offshoot of an earlier project which focused on assessing gaps and uncertainties in existing data and models and developing a causal analysis framework for LUC. In FY 2015 the focus of this project transitioned to the development of an independent land cover change detection method using satellite data and a semi-supervised change detection model was developed based on the feedbacks of the 2015 Peer Review.

  The objective of this project was to develop a land cover change detection method which can be used to rapidly estimate changes in land cover using very high temporal resolution (8-16 day) satellite data. Our previous analysis has shown estimating land cover changes using derived data products has unacceptable amounts of uncertainty stemming from data aggregation and interpolation and time gaps in data production. With recent advances in computing it is possible to analyze massive amounts of data to extract information from high volumes of multi-temporal satellite imagery. This is especially critical for identifying changes in vegetation which has a natural phenology depending on location and climate and which can also be impacted by natural (e.g., hurricanes and drought) and man-made phenomenon (e.g., fire and LUC due to bioenergy). The goal of this project was to provide tools and datasets to accurately assess changes in land use and land cover as consistent and reliable datasets is lacking and not investigate the causal relationship between LUC and bioenergy growth as interpreted by most reviewers.

  Using the developed algorithms and the causal analysis framework test case studies for various types of feedstock (i.e., crop, cellulosic, and pellets) and for various geographic locations can be investigated to determine the causal relationship between bioenergy and LUC as the next logical step in this project. Recent publications have correlated the reduction in grassland to the growth of biorefineries and reduction in forest cover in the Southeast due to the demand for wood pellet raising concerns about the environmental benefits and sustainability of bioenergy. An evidence-based analysis would provide a scientific basis for such concerns and help meet BETO's sustainability goals.

BIOFUELS NATIONAL STRATEGIC BENEFITS ANALYSIS

(WBS #: 4.1.2.41)

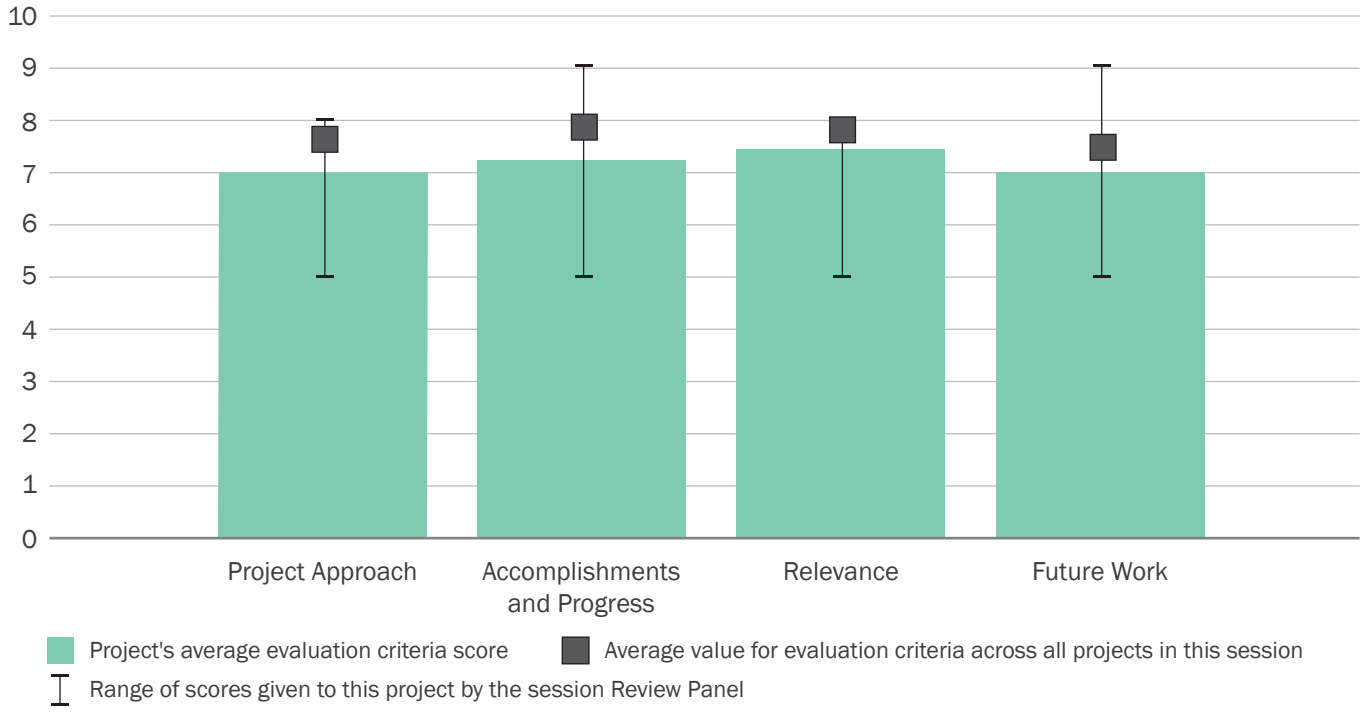
Recipient:	Oak Ridge National Laboratory
Principal Investigator:	Paul Leiby
Project Dates:	10/1/2011–9/30/2018
Project Category:	Ongoing
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$300,000
DOE Funding FY 2015:	$350,000
DOE Funding FY 2016:	$200,000
DOE Funding FY 2017:	$300,000

Project Description

This project helps DOE assess, quantify, and communicate the current and potential benefits of biofuels with an emphasis on energy security and fuel market outcomes. BETO funding started in FY 2012 building on prior ORNL work on alternative fuel transitions and energy security for DOE and EPA. A key impact expected from this project results from conveying to target audiences the multidimensional nature of the energy security concept as it relates to biofuels. Multiple energy security attributes (i.e., impact of biofuel on fuel price levels and volatility, and economic sustainability for supply chain participants) are explored using a suite of tools including a partial equilibrium model (BioTrans) to simulate market outcomes under a variety of scenarios and econometric analysis of historical market data. Challenges include model benchmarking and validation and the adequate representation of shock dynamics and impacts, as well as consumer/producer expectations and behavior. Key outcomes in the FY 2015–FY 2017 cycle include the following: (1) BioTrans simulations show the mechanisms through which biofuels mitigate retail fuel price changes and costs during oil supply shocks, (2) updated estimates of the energy security premium of biofuels reveal a decline in the monopsony component

Weighted Project Score: 7.2

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



of the premium but continued value from reducing expected macroeconomic shock costs, and (3) estimation of the volatility dynamics of gasoline and ethanol indicate modest reductions in fuel price volatility through biofuel blending.

Overall Impressions

- The Biofuels National Strategic Benefits Analysis team seeks to assess, quantify, and communicate potential fuel market impacts, economic advantages, and security benefits associated with biofuels by combining equilibrium modeling of markets and policies with historical market data. The focus has been on the interactions between petroleum- and biofuel-based U.S. fuel supply chains. The project utilizes an interdisciplinary team and many of BETO's existing models. The project is well managed internally and with external partners through frequent communications and close collaboration. Of particular importance is the team's focus on validation using model comparison exercises, peer review, and benchmarking. Since the last Review, the team has provided a detailed exploration of the impacts of oil supply shocks under a variety of market contexts, updated energy security premium estimates associated with biofuels, and developed econometric estimations of the relationship between volatility of biofuel and petroleum fuel prices based on historical market data. I found it interesting that increased ethanol use could reduce volatility and mitigate price increases in gasoline. This group looks at the 'what if' scenarios. This type of work could be very helpful to the Co-Optima team as they move forward with the rollout of various blendstocks. Being able to better understand, measure, and communicate the economic impacts as well as the social benefits or risks of greater biofuel use under various market and policy scenarios is very beneficial and could help to provide insight on strategies to effectively achieve an economically sustainable advanced biofuels industry. This is huge, and again an enabler for the Co-Optima project, in understanding the role and implications of biofuels in changing market contexts to help guide strategic planning. In the future, the team plans to look at biomass supply shocks since, while biofuels help mitigate the costs of oil, the biomass feedstocks used to produce biofuels are subject to shocks of their own due to drought and other factors. One thing I would encourage the team to look at is the impact of biobased chemicals and bioproducts. We are seeing an increase in the production of these materials which could spill over into the biofuels space and serve to reduce the volatility of the system. One example of this is the ability of the Brazilian sugarcane plants to shift between sugar and ethanol production mitigating the price swings of both.
- This is interesting work. A small point, but I challenge the team to question if the "selected empirical analyses" are the most appropriate to address the broader project mission. I also would find utility in increased communication/integration with other BETO efforts; this project seems relatively unique in the questions it seeks to answer, so the question is how best to inform other efforts.
- This is an interesting and useful project to include in the BETO portfolio. In order to make it as useful as possible, it would be good to be more explicit about the welfare gains achieved by reductions in uncertainty. Consumers and producers may have different attitudes to price uncertainty, just as they have to price levels, and these might be the subject of further analysis. One of the more compelling arguments for biofuel development may be as a sort of hedge against uncertainty in the supply (and, hence, prices) of other energy sources, and it might useful to consider how this would be expressed, perhaps via a real options approach (or equivalently?) in terms of its "beta" with other investments.

- This is one of the more valuable and innovative projects in terms of building the base of evidence for the rigorous evaluation of bioenergy economic and security benefits. The empirical, econometric focus is important.

  In addition to forward-looking modeling of alternative scenarios, the project might also estimate the value of historic policies retrospectively.

  It would be valuable to contextualize the role of biofuels in terms of energy security benefits with a comparison with other potential measures to achieve similar goals including the strategic petroleum reserve, energy efficiency measures, and other types of non-fossil energy diversification.

- The presentation includes responses to comments from the 2015 Peer Review. These two comments are particularly relevant and it is urgent that they are addressed in the near-term for the project to be relevant and impactful.

  2015 Comment: "I don't see how the work is being related to the public policy space/is making impacts, particularly if the publications/deliverables are not available online."

  PI Response: We will make it a priority that our work becomes more visible and clearly linked to issues facing decision makers in the policy space. For future work, we have proposed more of an outreach effort, including a visible website area and/or a workshop highlighting our results and related work by others, as well as the pursuit of high-visibility external publications. One major goal is to show how volatility and shocks influence the economic and social benefits of biofuels and to inform the research and policy community on how resilience strategies can enhance those benefits.

  A Google search for BioTrans ORNL yields only the 2015 Peer Review presentation. A Google Scholar search does not yield any relevant hits.

  2015 Comment: "There would be much value in seeing planned future work integrated with the results of work to date in an interim report. The project appears to be developing numerous sub-analyses of the fuels and bioenergy market. However, the material and conclusions need to be periodically tied-up together so broader themes are easier to follow."

  PI Response: We acknowledge the need to better tie up together the results and insights from the various tasks and modeling approaches we are using in this project. We have cited as one of our objectives for the future of the project to develop a website to host interim working papers and publications and to explain how all relate to the central topic of explaining and quantifying the economic and energy security benefits of biofuels.

  It would appear that the publication cited in Slide 22 (Leiby, Paul N. and Rocio Uria-Martinez (2017) "Biofuels Blends and Fuel Price Volatility—A Portfolio Analysis," ORNL Report, February.) addresses this comment, but the report does not appear to be publicly available.

  For this project to have an impact, the results must be published, preferably in peer-reviewed journals.

PI Response to Reviewer Comments

- The reviewers strongly recommend focusing on communicating our results, through peer-reviewed publications, discussions with stakeholders, and "increased communication/integration with other BETO efforts." These are all important, and we are making these communications a high priority this fiscal year. The FY 2017 work plan has a decided focus on result dissemination. We recently submitted a paper analyzing the role of biofuels in response to oil supply shocks to a peer-reviewed journal. We are working to also submit the econometric analysis of biofuel effects on fuel price volatility. In

addition, our FY 2017 Q4 milestone consists of two deliverables: (1) the release of a web interactive tool in which users will be able to explore results of BioTrans scenario simulations and empirical analysis, and (2) a companion paper summarizing insights from the simulation of oil supply and biomass supply shocks. We have adopted an efficient strategy to implementing this web tool (using RStudio/ RShiny). We will share a beta version of the web interactive tool with other researchers and industry stakeholders to receive feedback on results and the user experience to ensure the content presented is useful for the targeted audiences.

In terms of interactions with other BETO researchers, the reviewers note "Of particular importance is the team's focus on validation using model comparison exercises, peer review, and benchmarking." We have done paired model comparisons with BSM, are participating in the BETO Model and Tool Mapping project, the BETO Bioenergy Modeling Workshops, and will be BSM Beta Testers (focusing on comparing model behaviors and identifying opportunities to propose BSM extensions with insights or approaches from BioTrans).

In addition, we will reach out to other BETO teams to exchange insights and approaches that may advance our collective efforts. One prime example is to see how we can, as the reviewers suggest, "be ... helpful to the Co-Optima team as they move forward with the rollout of various blendstocks." We do think BioTrans, and the supporting empirical analyses related to fuel price volatility, can help BETO and Co-Optima team understand and measure economic impacts and benefits/ risk. We can also the BioTrans model to evaluate the economic benefits of some of the biofuel system engineering designs being analyzed by others, such as flexible multi-feedstock biorefineries, advanced biomass logistics systems, and bio-co-products techno-engineering analyses design configurations. Each of these could help diminish or diversify risk and provide benefits. As the reviewers indicate, biobased chemicals and bioproducts will likely have economic impacts that spill over to biofuels, and could alter the volatility of prices and diversify the risks to biofuel supply chain participants. We have identified this as a prime candidate for follow-on research. Finally, we can offer the biofuels energy security premium calculation as a $/gallon metric that can be used by other projects to incorporate expected energy security benefits.

The reviewers have suggested a number of promising areas for further application of our work, and for extensions. One commenter notes that, "In order to make it as useful as possible, it would be good to be more explicit about the welfare gains achieved by reductions in uncertainty." We agree that changes in uncertainty and volatility can be influential and valuable, and we need to extend the current welfare measure to account for that. We are also looking at other energy security measures and real options theory.

In summary, we gratefully accept the cautionary comments and the recommendations that we stay focused on maximizing the impact of our work through carefully focused research efforts, communications, and peer-reviewed scientific output. We are excited about the ideas for further research. We are also very encouraged and appreciative of the comments regarding the value and innovativeness of our project.

BIOECONOMY ANALYSIS

(WBS #: 4.1.2.42)

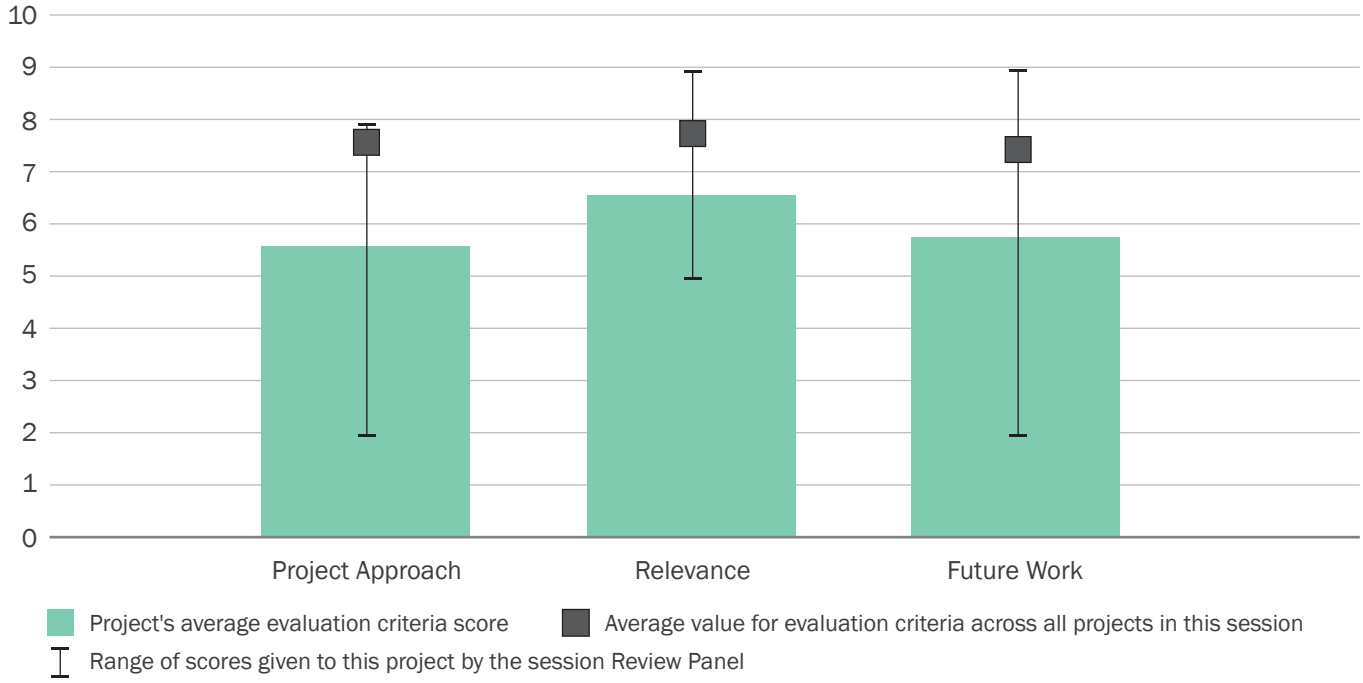
Project Description

Recipient:	Oak Ridge National Laboratory
Principal Investigator:	Laurence Eaton
Project Dates:	10/1/2016–9/30/2019
Project Category:	New
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$0
DOE Funding FY 2015:	$0
DOE Funding FY 2016:	$250,000
DOE Funding FY 2017:	$250,000

The bioeconomy vision projects an increase in biomass utilization to three times the current level, with bioproducts contributing up to 50 billion pounds of output by 2030. However, the path to achieving this vision is not well understood from current analyses. Questions such as price sensitivity of particular chemicals, the number of new facilities, and maximizing the value of biomass under a dynamic market remain critical to technology commercialization success. The project's main objectives are threefold to provide DOE and technology stakeholders with a quantitative economic assessment of (1) the determinants of demand in the bioeconomy; (2) interactions among biofuels, biopower, bioproducts, and fossil products; and (3) the economic sustainability of the U.S. biofuel industry through integrated modeling using TEA, LCA, and market data. Although market interactions are expected to induce a combination of important negative and positive impacts on the biofuel industry, the net effects can only be understood through formal quantitative economic analyses. This information is critical to support policies and R&D efforts to help meet the strategic goal of maximizing the economic, environmental and social benefits of biomass to the U.S. economy (2016 *Multi-Year Program Plan*). The project will use findings from the recent interagency Bioeconomy Analysis and laboratory market analyses as

Weighted Project Score: 6.0

Weighting: Approach–25%; Relevance–25%; Future Work–50%.



the starting point to examine the economic case for the bioeconomy vision.

Overall Impressions

- This project explores the economic ramifications of various strategies in developing the bioeconomy and seeks to understand the economic, social, and environmental implications. As a new project, the team hopes to design and develop novel economic approaches and tools to identify and measure the interactions among biofuels, biopower, and bioproducts along with conventional fossil products through integrated modeling using TEA, LCA, and market data. It is an interagency effort led by BETO and is comprised of a team with expertise in energy and agricultural economics. Collaboration and communication will be key in achieving maximum value from this project. The outcome of this project is to provide BETO and decision makers with price and economic impact tools needed to determine the best use of biomass resources as well as the demand drivers and sustainable commercialization pathways needed to expand the bioeconomy. The team will use economic principles combined with techno-economic and market data to explore feasible bioeconomy alternatives. The strength of this project is in its desire to answer critical questions around the marketing of bioproducts as well as looking at the role of bioproducts in advancing biofuels. These are worthy goals and much needs to be done in this area. However, I would caution the team against reinventing the wheel and taking advantage of the information already generated by other BETO projects because this project, on the surface, appears to overlap with other projects. I would ensure the work is focused on the gaps in BETO's understanding. Future work incudes updating empirical data on fossil and biobased products including market size and structure, costs, and technologies that are most relevant to the biofuel industry; estimating the impacts of bioproducts on the competitiveness of advanced biofuel technologies including the cost of meeting the biofuel policy targets; and stimulating the economy-wide impacts of bioproducts.

  Most of the work outlined by the team deals with the interactions between bioproducts and biofuels. I was confused about what the team proposed to do in regard to the interaction with biopower and urge the team to carefully consider the boundaries of the study (e.g., do you consider biomass pellets to Europe?). Developing specific goals and engaging with stakeholders will help to focus the project. Understanding the impacts of regulation will also be essential. I would urge the team to build on the work already done at CEMAC as well as BIC best uses of biomass tool developed in a former NREL study. Finally, understanding how to maximize the market opportunities for bioproducts alone will ultimately spill over into the biofuels space. Therefore, I see task 4, the evaluation of the potential penetration of bioproducts under alternative future market scenarios and analysis of cascading supply chains for biobased products, as key.

- The objectives and high-level approaches seem reasonable. It is difficult to judge the absolute appropriateness of the methodology given the lack of details available at this point.

- This project describes an ambitious agenda for economic modeling of the development of bioproducts. More details need to be filled in, however, in order to understand how this is to be done and how the results may be useful. It would be helpful to have clear criteria established to grade the interim achievements of the project. In this regard, it's important not only that the models developed be able to explain certain sets of data (this can always be done by creating sufficiently complex parameterizations), but also to predict outside of the data to which the models are calibrated.

- This project seems very well positioned to make an important contribution to analyze the bioeconomy potential market and environmental benefits and possible trade-offs. It should provide valuable inputs to developing an evidence-based strategy, helping to motivate other projects by providing the bigger picture as to how bioproducts fit into a strategic approach. It would be important to ensure this project draws as much as possible on other findings and projects. It will also be important to make sure that environmental as well as economic considerations are central.
- This project should undergo a round of planning focused on establishing clear milestones that can be accomplished on a quarterly/annual basis, identifying datasets and relationships to other efforts to allow for efficient project execution, and establishing a plan for managing project risks.

  A useful first step for this project would be to prepare datasets detailing factors involved in the price of conventional fuels and chemicals, biofuels and biochemicals, and other new fuel and chemical pathways likely to enter the marketplace in the near term. These data could play an important role as inputs to other models.

  This project should not have produced a tool as an aspiration until it has prepared data, done case studies, established an analysis framework, engaged and understood the needs of stakeholders, and more generally proven its worth.

PI Response to Reviewer Comments

- Thank you for these comments. Acknowledging the breadth and depth of the bioeconomy, with previously disparate industries now paired together, it is a challenge to model everything simultaneously. While the focus of BETO has shifted toward bioproducts with biofuels, a larger vantage is required to consider the multiple input and output markets involved within the bioeconomy.

  We agree with the surface-level appearance of overlap with existing projects in the BETO portfolio. It is likely that this impression was created by lack of emphasis in the presentation on how we intend to link this project with existing efforts through data and information gathering from existing BETO laboratory projects, such as CEMAC, strategic analysis, conversion, and ORNL feedstock analysis using an economic framework. It is this economic modeling and analysis approach detailed in additional responses below that will uniquely differentiate this project within the portfolio. Therefore, we hope to not reinvent but rather complement the analysis, both ending and ongoing, through synergies and collaboration.

  Several analyses have focused on the potential to expand the bioeconomy, but have lacked rigor in detailing the price interactions of markets, demand determinants, and the potential limits to expanding small and dynamic sectors, such as chemicals from biomass. The economic modeling tasks, therefore, are focused on four main areas: (1) collection of detailed time series data of bioeconomy market segments (building upon findings from previous projects); (2) market demand analysis (elasticities within and between markets) and supply analysis from BT16 and other analyses with conversion TEA information; (3) use a partial-equilibrium market framework to evaluate how policy, market, and other factors determine the bioeconomy outcome, accounting for cross-sector relationships; and 4() simulate biomass benefits nationally within an input-output modeling framework.

  The initial tasks are to develop datasets of information of the bioeconomy and new chemical pathways based on BETO analysis. It is noted that this information changes due to market dynamics and interest from BETO's perspective, so frequent revisiting will be required to ensure data for modeling are current and reflect state of industry and conversion science.

Biopower and pellets are of interest as potential sources of feedstock competition for new industrial uses. The purpose of including these would be to identify and account for changes in demand for existing and new biomass as projected by DOE's Energy Information Administration and other forecasting groups.

USDA has noted that the limiting factor of bioeconomy expansion is the availability of feedstocks, for which production may have significant environmental impacts.

The statement about caution toward developing a tool at the infancy of a project is wise and will be considered. This output was identified when the project took shape as a potential public output. However, the production of such a public tool will take place later in the life of the project after several iterations of data collection and modeling. The steps to create a public model would be deliberate, peer reviewed, and vetted with stakeholders through user testing. This will be considered in the revisiting of the project plan and outputs.

We have identified and are in communication with relevant BETO-funded projects including INL's work on pellet market analysis. We recognize the role of regulation for biofuels and that it is likely to be crucial for bioproducts, thus making this part of our project's efforts.

GCAM BIOENERGY AND LAND USE MODELING AND DIRECTED R&D

(WBS #: 4.1.2.50)

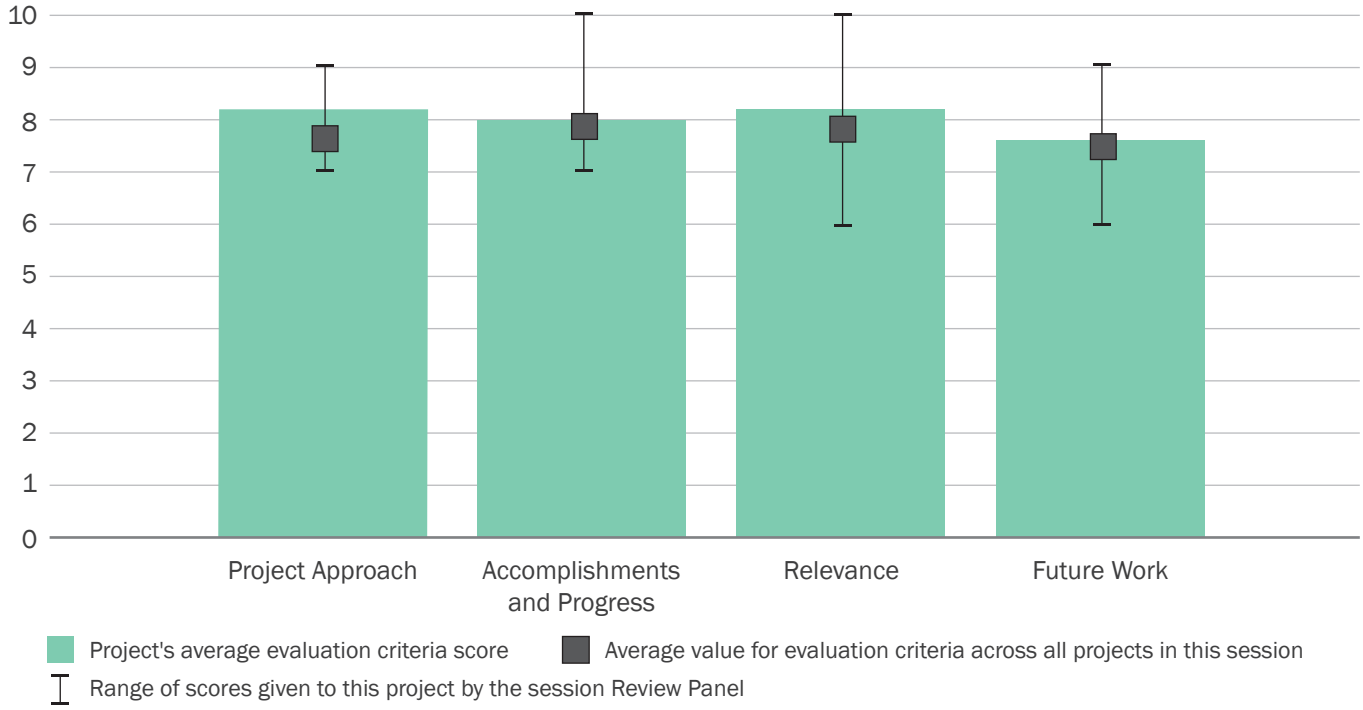
Project Description

Recipient:	Pacific Northwest National Laboratory
Principal Investigator:	Marshall Wise
Project Dates:	10/1/2010–9/30/2018
Project Category:	Ongoing
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$150,000
DOE Funding FY 2015:	$150,000
DOE Funding FY 2016:	$150,000
DOE Funding FY 2017:	$150,000

This project provides global modeling and analysis of bioenergy questions using the PNNL Global Change Assessment Model (GCAM). This project is relevant to BETO's A&S Technology Area as it analyzes bioenergy in the integrated context of global energy and agriculture. The GCAM project is an established, multi-client effort ongoing for over two decades. GCAM is widely used by DOE and EPA, participates in international analysis efforts such as the Intergovernmental Panel on Climate Change (IPCC) and Stanford Energy Modeling Forum, and is an open-source community model available to all. This BETO project leverages the GCAM program to focus on improving modeling capabilities, data, and analysis in key areas related to bioenergy production and use. Beginning in 2010, technical accomplishments include published analyses about lignocellulosic bioenergy crops, bioenergy technologies for liquid fuels and power, and bioenergy with carbon dioxide capture and storage. FY 2013 and 2014 focused on modeling water demand parameters for bioenergy produc-

Weighted Project Score: 8.0

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



tion. For FY 2015 and 16, we analyzed the potential and impacts of large-scale production and use of biofuels for aviation and freight transport using the transportation demand sector of GCAM. Currently in FY 2017, we are studying the multi-sector, integrated potential and impact of bioenergy considering competing technologies across the energy system.

Overall Impressions

- The purpose of this project is to perform integrated analyses of bioenergy sources and technologies in a global modeling framework. Because this project serves a support function, it is critical to carefully define what key bioenergy A&S questions are going to be part of the analysis and model development efforts. The project appears to be well managed and is strongly leveraged internally with other BETO projects and externally across multiple agencies and several industrial partners. It is good to see the close collaboration, model vetting, and detailed documentation throughout the project. The aim of this activity is to provide timely, relevant bioenergy analyses through the continued development and maintenance of GCAM. Since the last review, GCAM focused on the energy sector by analyzing the potential scale and context for aviation biofuels as a way to reduce GHG emissions and the dependence on fossil fuels. The team also looked at the role of biofuels to meet a growing demand for on-road freight transportation. I found it interesting that when modeling global bioenergy potential, the team found that food crop yields were key. Getting developing countries to adopt the use of hybrid seeds and modern agriculture techniques would go a long way in supplying the global food supply and fuels. This project provides a long-term economic, multi-sector, policy, and international context for bioenergy considering energy, agriculture, and emissions. The work done on this project complements other BETO-sponsored tools and research. It is great that the analyses and model developments done as a part of this project are made publicly available. It is great to see that the model has been picked up and used in other studies. I also applaud the group for its continued efforts in validating the model since understanding the global ramification of the bioeconomy is a complex issue. Future work specifically includes looking jointly at bioenergy for power, gas, and liquid fuels for passenger and freight transportation as well as carbon capture, utilization, and storage. While the strength of the model is its ability to look at the larger global picture, it would be helpful to better understand how this model relates to other economic models such as those from the Food and Agricultural Policy Research Institute (FAPRI) and Global Trade Analysis Project (GTAP).
- I do not have any concerns about this project, nor do I have any specific comments or suggestions to improve upon it. GCAM is widely used by a variety of users and for a variety of analyses. The connection to other BETO modeling efforts was noted and appreciated. Model management, updates, and analyses seem to be conducted in an open, transparent, and collaborative manner. Demonstrated use of the model by those unaffiliated with BETO is a strong indication of GCAM's relevance to a broader community.
- I find this a very strong and appealing project for two reasons: (1) it leverages substantial investments already made in GCAM, an integrated climate assessment model and (2) it is part of a larger climate modeling effort, it allows "apples-to-apples" comparisons of alternative approaches to addressing climate change.

  In addition to these aspects, the possibility of integrated economic modeling to locate areas in which additional production of biomass might be situated, as well as areas to which food production might be displaced, may provide a useful modeling platform for predicting LUC.

- The project leverages the capabilities, recognition, and availability of GCAM. The main strength of the project is ensuring the capability of GCAM for answering bioenergy-related questions and having access to the modeling team for targeted requests. Ensuring relevance depends on the particular questions being asked that best maximize the value of the tool. For example, the most recent analysis on aviation addresses a timely topic but it is unclear that a single sector study fully leverages the GCAM platform. Deploying GCAM to answer the types of questions it is suited for or making it available more widely to take advantage of these capacities should be a priority for future work including the proposed passenger and freight and carbon capture and storage analyses. Displaying and sharing data and results via the Bioenergy KDF or BIC should also be considered.
- This is a data-intensive, complex model with significant maintenance requirements. BETO should decide whether to invest significantly in maintaining and developing this model for understanding LUC associated with biofuel systems. The model's financial health should also be considered in terms of other sources of funding.

  Given the complexity of the model and the data requirements, it would be helpful to consider how it might be used beyond analysis of LUC. This project is very similar to the aspirational plans of the project led by PI Eaton. It would be helpful to manage these two projects together such that Eaton's work feeds in to GCAM and GCAM could be applied to answer questions posed by Eaton.

PI Response to Reviewer Comments

- Thank you to all the reviewers for your time and attention. These Peer Review efforts have been extremely valuable in helping to focus the scope of this project in the context of BETO.

We have worked with BETO to define the complementary roles of GCAM among its modeling tools. FAPRI, Forest and Agricultural Sector Optimization Model (FASOM), and GTAP are other prominent economic modeling efforts that consider bioenergy but also have broader user groups and audiences. FAPRI and FASOM are both valuable in that they can focus in detail on specific crop markets and forestry with much smaller regional resolution in the case of FASOM. GCAM incorporates less-detailed representations of these sectors in most instances, but it considers them in a dynamic global context that importantly includes the detailed energy system. GTAP is different in that it is a general equilibrium model covering the entire economy with a strong focus on near-term agriculture markets and trade. GCAM complements this by having a longer-term focus with more technology detail in the future energy system.

The suggested interaction with the bioeconomy analysis project is appreciated. We have used the bottom up detailed analysis in *BT16* (and the other two reports in the Billion-Ton series, the 2005 *Billion-Ton Study* and the 2011 *U.S. Billion-Ton Update*) to crosscheck the feasibility of bioenergy results we see in GCAM scenarios. We could provide a further link in the other direction by providing the potential scale and roles of bioenergy long-term and globally in the context overall energy and agriculture.

Finally, we should and will provide a link to GCAM and papers on the Bioenergy KDF.

IMPACT OF PROJECTED BIOFUEL PRODUCTION ON WATER USE AND WATER QUALITY

(WBS #: 4.2.1.10)

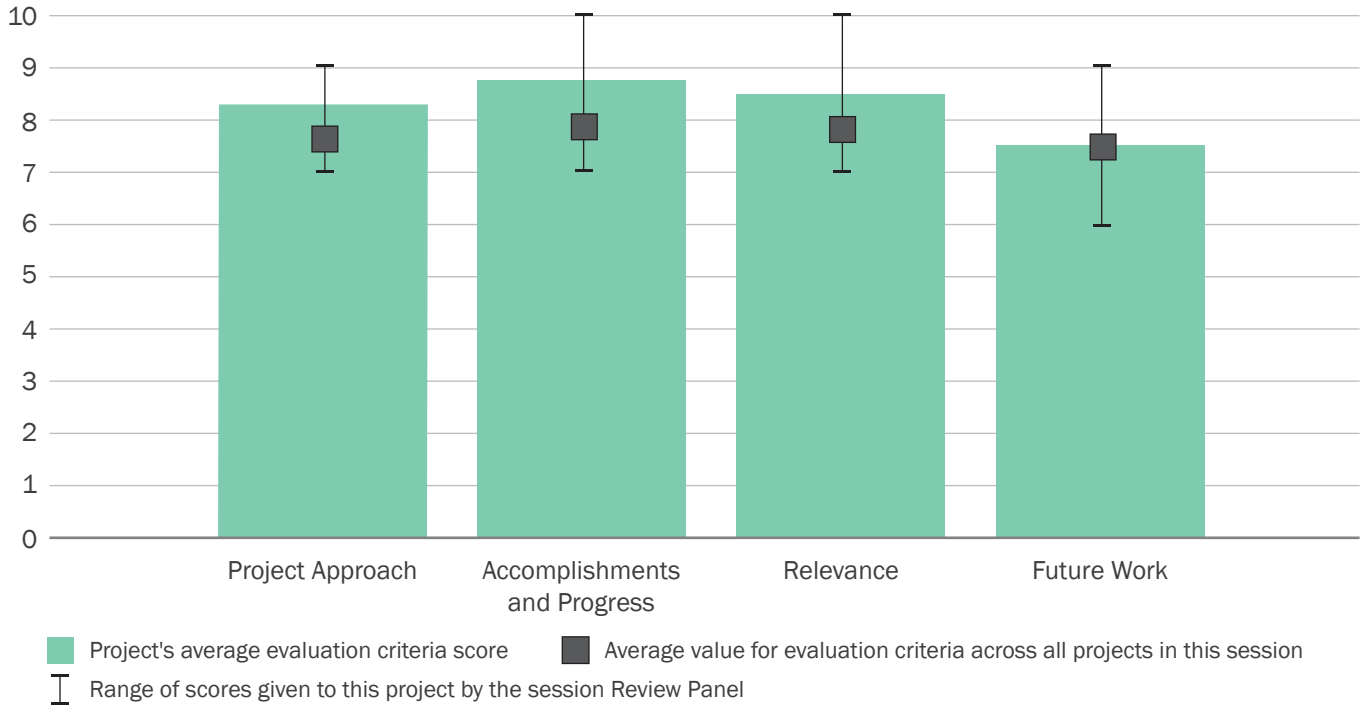
Recipient:	Argonne National Laboratory
Principal Investigator:	May Wu
Project Dates:	10/1/2010–9/30/2017
Project Category:	Ongoing
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$650,000
DOE Funding FY 2015:	$625,000
DOE Funding FY 2016:	$725,000
DOE Funding FY 2017:	$714,310

Project Description

This project develops an analytical framework and models to quantify the relationships between bioenergy production and water use, quality, and resource availability with spatial resolution; evaluates management practices in bioenergy landscapes that protect water resources and increase water use efficiency; and identifies scenarios that improve the water sustainability of advanced bioenergy systems. Outcomes of the project are geospatial analyses of national-scale and county-level water footprints of biofuels; a spatial-explicit model, WATER; an energy-water resource inventory; and a suite of multi-scale Soil and Water Assessment Tool (SWAT) hydrologic models. Since the 2015 Peer Review, this project (1) assessed the water footprint of six *BT16* scenarios for agriculture and forestry, (2) developed a SWAT model for the Iowa River Basin and examined the effect of a *BT16* scenario that includes various conservation practices (i.e., cover crop, tile drain control, slow-release nitrogen fertilizer, and riparian buffer) on water quality, (3) developed a SWAT model for the Lower Mississippi River Basin, (4) analyzed the management of biorefinery wastewater for a biological sugar-to-hydrocarbon process, and (5) developed methodology for the representation of water availability. In addition, the PI became a member of the Hypoxia Task Force modeling group. Output from this project feeds directly

Weighted Project Score: 8.3

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



into biorefinery TEA/supply chain sustainability analysis and the development of sustainability indicators.

Overall Impressions

- The goal of this project is to establish quantitative metrics to identify and select water sustainable scenarios in the production of bioenergy and bioproducts. The project goes beyond looking at just water consumption to also look at the broader metrics of water quality and availability. This is important as many places here in the United States, as well as globally, face water shortages and other challenges. The project has a well-defined approach and encourages transparent analysis. The emphasis on collaboration is excellent and critical in obtaining the necessary data and stakeholder engagement. Having the WATER tool open access also adds to the transparency and rigorous validation of the model assumptions. The technical accomplishments of the project were extensive and included contributions to two chapters in the BT16 report as well as six BT16 agriculture and forest scenarios. This was a great way to highlight the hard work that has gone into producing this model and the current level of maturity in the analysis tools. The past two years have also seen the extension of the model to include best management practices for water quality improvements and the addition of new pathways in the WATER model. A key accomplishment since the 2015 review has been to look at the temporal and spatial variations in rainfall and water availability to meet energy crops and biomass production. This project provides the necessary framework to examine water sustainability metrics for biofuel and biomass production that goes beyond water consumption and looks at water quality and availability metrics. This will be critical as the bioeconomy grows. Future work will include the release of the water resource availability index for several agricultural and forestry scenarios as well as improved guidelines for biorefinery wastewater management options and treatment schemes. This will be very helpful in reducing water usage, improving biorefinery design, and mitigating costs associated with wastewater treatment. It was suggested in the 2015 Peer Review that algae because of its high-water use and ability to use gray and salty water would be a great addition to the model. When asked about looking at algal systems, Dr. Wu said that the technology is still immature at this time but that they have plans to look at it in the future. I would like to encourage BETO to do this since water is such an integral part of the algae system. It would complement BETO's ongoing work on algae and add a robustness to water modeling.
- The project appears to be progressing well. Project objectives, outcomes, and future efforts are all reasonable. Accomplishments thus far provide interesting insight into the primary research question. Stakeholder engagement is strong. Consideration should be given to better engaging (or documenting existing engagement with) non-public sector entities, such as private industry or nongovernmental organizations.
- One issue that is common to treatments of water quality projections for the bioeconomy concerns whether biomass crops will have different environmental effects than do existing crops. A number of measures might be taken to make growing biomass more environmentally benign, but similar measures might also be adopted to reduce runoff and other negative effects from existing crops. This really goes beyond the scope of this project per se, but it is important to consider more generally how BMPs that would enhance environmental performance might be implemented in the absence of regulatory drivers.
- Overall, this project is core to developing BETO's capacities on the water impact side. It would be helpful to explain how this project complements other water modeling efforts in government and aca-

demia for the same regions, as well as related work for other regions, and to think about how the results can best be disseminated and made useful to stakeholders particularly in terms of the planned water management guidelines.

It would also be valuable to use the model to compare the water impacts of energy scenarios with bioenergy vs. other energy alternatives.

PI Response to Reviewer Comments:

- The project team expresses its deep appreciation to the reviewers for their time, encouragement, and valuable input. We also thank the reviewers for recognizing our accomplishments and providing future directions. To broaden the reach of our research, we are working on a plan to disseminate data, communicate results, and promote the tools developed as a result of this work to the scientific community and general public via various channels, including peer-reviewed journal publications, webinars, and other means of communication. Looking forward, as part of our project plan, we will consider adding an algae pathway to WATER and address the impacts of the non-bioenergy and electricity scenario on water resources. We will continue to work with other federal agencies and research institutes on modeling comparisons for the Mississippi River Basin and its tributaries and regional watersheds to address impacts on water quality. In addition to working with federal agencies, we will increase engagement with private sectors in biomass production and wastewater management. Finally, we will stay focused and continue our contributions to BETO, as well as to the development of the bioeconomy.

INTEGRATED LANDSCAPE MANAGEMENT

(WBS #: 4.2.1.20)

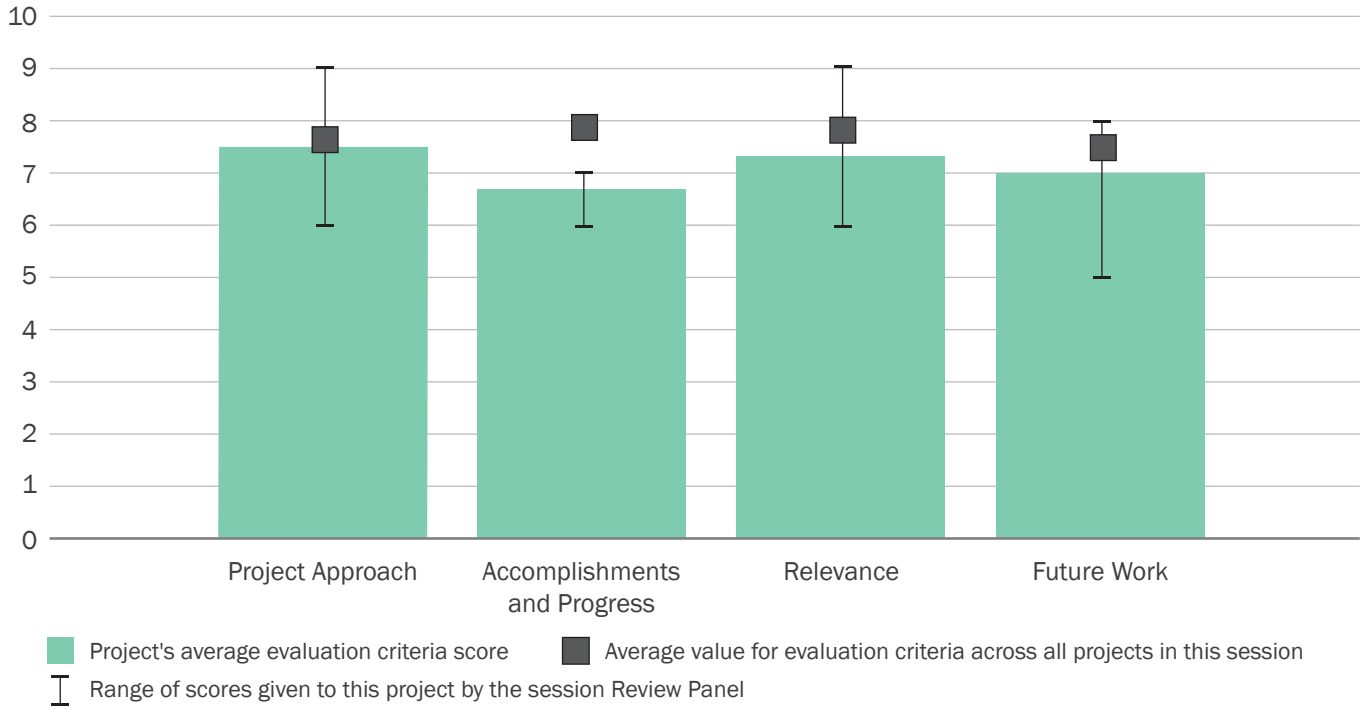
Recipient:	Idaho National Laboratory
Principal Investigator:	Shyam Nair
Project Dates:	10/1/2006–9/30/2017
Project Category:	Ongoing
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$300,000
DOE Funding FY 2015:	$450,000
DOE Funding FY 2016:	$450,000
DOE Funding FY 2017:	$550,000

Project Description

Biomass supply systems solely dependent on agricultural residues are subject to strict limitations and risks in feedstock availability when soil health, offsite environmental impacts, uncertain growing conditions, and producer economics are considered. This project, started in FY 2015, is designed to increase overall biomass production, reduce grower losses, and improve soil and water quality. In FY 2017, another environmental component has been added to the project for the estimation of the reduction in nutrient loading to water bodies from wash off of nutrients from agricultural watersheds as a result of energy crop integration into the agricultural landscape. By utilizing subfield management and decision tools to integrate energy crops into the landscape, field-level profitability can be improved, annual biomass availability can be increased, and logistics costs can be brought down. The project has shown the feasibility of meeting the $84/dry ton feedstock cost target and the potential to significantly increase biomass production by integrating energy crops into agricultural landscapes through analyses of four counties in the United States. Efforts are ongoing to expand the analysis to all relevant counties in

Weighted Project Score: 7.1

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



Kansas and Iowa and deploy the products of the analyses on the Internet. For the bioeconomy to be sustainable, the bioenergy industry must have a long-term, sustainable, and adequate supply of its raw material, the biomass, at competitive prices.

Overall Impressions

- The goal of this project is to promote the sustainable production of biomass using innovative landscape design tools and to develop an analytical framework to promote changes that enhance the commercial viability of bioenergy. While similar in some respects to the Biomass Production and Nitrogen Recovery project, the team has taken a different approach. I applaud the team on its close connections with industry as well as local government and the farmers themselves. This will be essential to the success of the project. Helping growers to understand being able to grow more biomass and at a lower cost by targeting specific areas in their fields is critical. Getting their feedback as to the minimum subfield size that is doable from a planting and harvesting perspective and then using this in the overall integrated landscape design could be powerful. The work to date shows that an increase in overall biomass availability is achievable with the integration of energy crops resulting in lower cost and with minimal impacts to grain production. The team completed analyses in four counties in the United States showing the feasibility of sustainable integration of energy crops into row crop fields at costs that meet BETO goals. This project provides the framework and support for developing environmentally, socially, and economically sustainable practices for biofuel production. One thing that makes this project relevant is the team's efforts to engage land managers and growers, researchers, the biofuels industry, and policymakers in all aspects of the project. Another is the team's focus on lessons learned and applying what it has learned across differing landscapes and multiple regions. However, at present, the development of tools designed to support the farmer do not have a subfield level resolution. This type of scale will be required to make the work applicable at the individual grower level. Future plans include expanding the analysis to two states, integrating energy crops in row crop landscapes, and establishing viability across diverse and diversely managed lands. I applaud the team's goals to develop and deploy a web-based tool set, data sets, and analysis results. Much more can be done as is outlined in the team's plans for moving the technology forward. I would, however, also encourage looking at some of the softer issues such as how to motivate a grower to integrate bioenergy into their plans, and how can we monetize for ecosystem services with things like clean water credits?
- Given the emphasis on "actionable information" and the connection of this project to other BETO-led efforts, I challenge the team to better communicate how the various components of the project will be rolled into an overarching framework. Successfully executing this portion of the project will have a strong influence on the project's ultimate reach.
- My overriding concern with this project really goes back to comments that were raised in its 2015 review, but weren't addressed in detail in the presentation. How plausible is it to exactly target areas within existing fields for growing energy crops? The assertion that farmers are currently losing money on these areas, but still farming them, makes a prima facie case that micromanagement is not feasible.
- This project seems to assume the planting bioenergy crops where grains are not profitable always benefits the land. I am concerned that future plans outline a complicated modeling tool with very little data to support it. Data collection and model development need to go hand in hand.
- This is a tool for targeting across a landscape based on economic as well as environmental character-

istics. The strengths are the sub-field granularity as well as the integration of different criteria. The integration of harvesting methods and costs based on subfield-level characteristics is also an impressive addition. The analysis seems to assume that there are more profitable bioenergy activities that farmers could pursue on parts of their fields that are not currently being taken advantage of. It would be important identifying what are the reasons that such economic opportunities are being overlooked or not pursued and doing some focus groups or field tests of the hypotheses. Also, it would also be important to explicitly incorporate assumptions about uncertainties and unobserved heterogeneity of land quality and other factors to examine how these are likely to affect the findings.

The public nature of the tool is very attractive. However, a main challenge is accomplishing the goal of delivering "actionable" information. Before investing in many of the possible next steps for the modeling, it seems essential to conduct more stakeholder engagement with the potential users to identify what would be most useful to deliver on the goal of "actionable" information at the producer as well as landscape planning levels.

- The project is making good progress in establishing the framework. It would have been nice to hear more about the pieces, how they work (e.g., what goes in and what comes out), and how they will/could be built together into a tool that is useable by stakeholders.

PI Response to Reviewer Comments

We will strive to better communicate how the various components of the project will be rolled into an overarching framework, as suggested by the reviewer.

In response to the reviewer's statement, "However, at present, the development of tools designed to support the farmer do not have a subfield level resolution," the framework is developed with subfield as the smallest unit and therefore results can be obtained at subfield resolution.

The goal of this project is to provide analysis on alternative production options that a producer may adopt to mitigate financial losses that are currently occurring at the subfield level, and are both financially and operationally feasible. While these practices, or any subfield alternative practices, are being widely utilized, our hope is that by performing this analysis we will increase the producers' options.

We agree with the reviewer that "It would be important identifying what are the reasons that such economic opportunities are being overlooked or not pursued and doing some focus groups or field tests of the hypotheses." Our project is designed to provide technical, sustainable, and economically feasible solutions to make subfields profitable, which can be used in focus groups and field tests.

Heterogeneity of land quality, climate and crops are explicitly factored in our assessments. However, because of the large computational requirements to assess tens of thousands of subfields within a county, explicit propagation of uncertainties using Monte Carlo-type methods are not feasible at present. In future work beyond FY 2017, we are proposing to incorporate uncertainty through sensitivity analysis using well-defined alternate scenarios of management practices, crop rotations, and nutrient applications, as examples.

We are working closely with Antares Landscape Design project to elicit stakeholder inputs with regard to scenario development and clearly defining actionable information from our toolset.

The project has defined a methodology to down-select from unprofitable subfields and focus only on those subfields which can meet or exceed yield and harvesting cost thresholds for residue and energy crop production. Therefore, the project does not assume that planting bioenergy crops where grains are not profitable always benefits the land.

BIOFUEL AIR EMISSIONS ANALYSIS

(WBS #: 4.2.1.30)

Recipient:	National Renewable Energy Laboratory
Principal Investigator:	Danny Inman
Project Dates:	10/1/2010–9/30/2018
Project Category:	Ongoing
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$600,000
DOE Funding FY 2015:	$550,000
DOE Funding FY 2016:	$558,000
DOE Funding FY 2017:	$650,000

Project Description

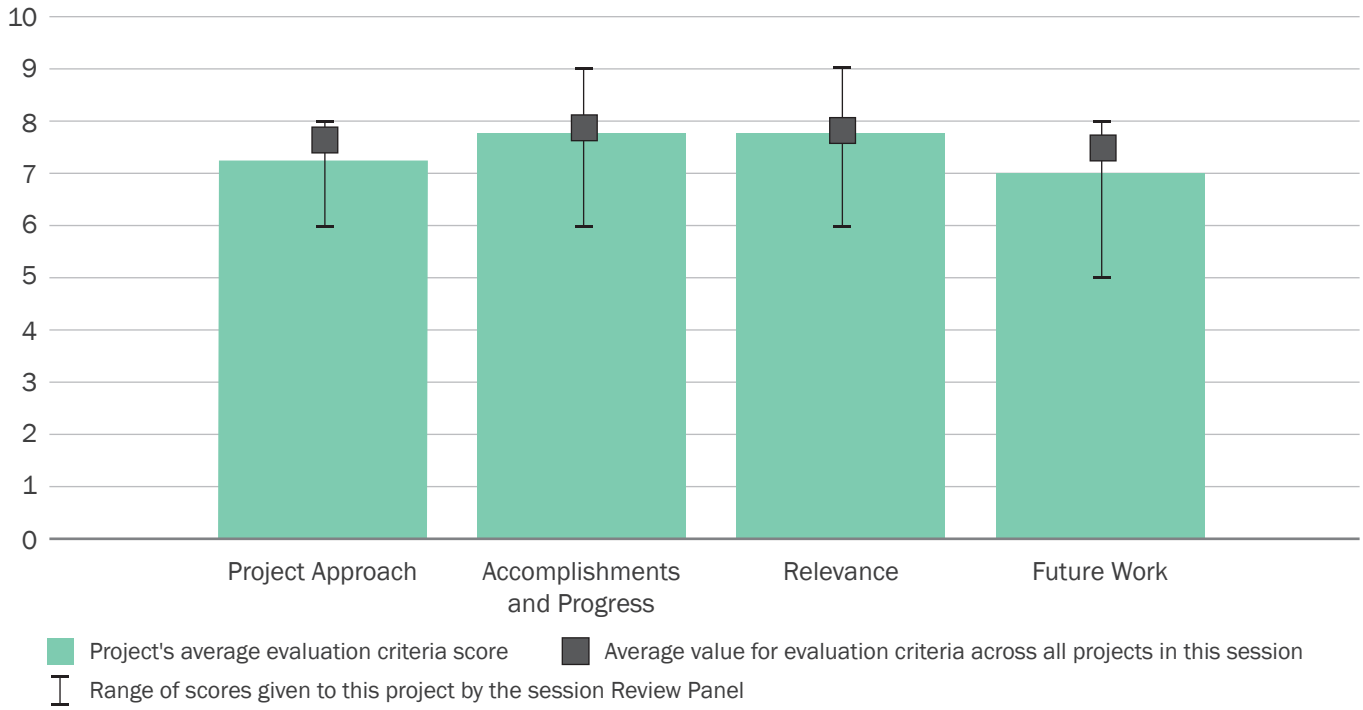
The public expects, and the biofuel industry implicitly promises, a more sustainable product across all environmental attributes as compared to conventional fuels. The goal of this project is to perform analyses to better understand air emissions from the biofuel supply chain, applicable air regulations, and implications for cost, operations, and sustainability. Project outcomes include information; data; and tools that will aid in many key decisions including process design configuration, location, and supply chain considerations. Our modeling approach combines work performed by other national laboratories, empirical data, emissions factors, process modeling, and a review of existing permits. Technical accomplishments include air quality assessment of *BT16*, regulatory analyses of DOE conversion technologies, cost implications of air-quality mitigation strategies, and air emission estimates for DOE conversion technologies. Future work will focus on continued assessment of DOE conversion technologies and the public release of the FPEAM.

Overall Impressions

- This project strives to better understand air emissions from various biobased processes across the entire supply chain in an effort to see how well these emissions meet applicable air regulations and the implications for cost, operation design, and environmental sustainability. The purpose is to use the

Weighted Project Score: 7.4

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



information gathered to aid future biorefiners and other decision makers in making the best choices in process design, biorefinery siting, and supply chain considerations. Because the intent is to impact decision makers, it is critical to interact with stakeholders throughout the project in order to solicit their input on project results and future direction. This project contributed significantly to understanding of the air quality and pollutant emissions for selected biomass production, transportation, and processing scenarios that were used in *BT16* by incorporating spatial and temporal distributions of air emissions and analyzing how these changes could potentially impact local air quality. The project also looked at new conversion processes such as the sugars to hydrocarbon pathway. These results will enable biorefiners to understand the cost implications of potential mitigation strategies thereby minimizing adverse impacts. Air quality is an important aspect of sustainability because of its potential impact on human health and the environment. Like ANL's water quality modeling, this project seeks to facilitate the sustainable deployment of advanced biofuels by providing estimates, in this case, of air quality and pollutant emissions across the biofuel supply chain. The model development and findings from this study enable air emission mitigation strategies to inform process and cost modeling as well as impact biorefinery and supply chain design considerations. It is particularly important to identify those parts of the process that cause a majority of the emissions so mitigating strategies can be taken to make the process more sustainable. Because this project seeks to inform not only the biorefiners themselves but local and federal air quality agencies, it is critical to get this information into the hands of the public and especially decision makers. It is good to see that the researchers are working to publish their findings in peer- reviewed literature. However, making the model publicly available would help to accomplish this goal. I would like to encourage the researchers to not only continue to build out the model by assessing new conversion technologies but to spend some time refining FPEAM so that it is user friendly and in a format, that can be shared with others.

- It is difficult to discern the true breadth (and therefore, contributions) of the project given the materials provided. Presentation materials were fairly general, so attention is necessary to more clearly identify the project, its specific outputs, the format and use of the outputs, and how outreach with external stakeholders will be conducted. It is clear that good work is being done, so the question becomes how best to communicate that.
- This project fills a niche that needs to be addressed in the interests of completeness: air pollution from biomass production and processing. The results suggest that these concerns may not be quantitatively very important, however (e.g., meeting regulatory requirements may have only about a 1% effect on costs). While it is useful to establish this, and the results of the project may be helpful in informing required permitting procedures, this may be a subject that does not merit a great deal of additional investigation. Just to be clear, I'm not saying that this effort is not good and useful, it is, but the utility of the project may lie in its definitive settlement of the issues it considered.
- The project is an important contribution to enable a view of the air quality impacts of bioenergy feedstock production. It will be critical to ensure that this framework either directly or in complement with other modeling can evaluate the downstream processing and combustion air quality impacts. This will be essential for providing a comprehensive comparison of air quality implications relative to fossil and other alternatives.

  The project also is important for its practical aim of providing decision support tools and directly supporting regulatory and planning processes at federal, state, and local levels. It will be important to ensure coordination and alignment with potential users to guarantee the highest value and applicability of the project.

PI Response to Reviewer Comments

- 1. Discussion of particular tasks and outputs would have been appreciated. Thanks for the input. In the future, we will provide more detail on tasks and output specifics.

  2. Define more specifically the regulatory and supply chain planning needs and how this project could help. We have performed several regulatory analyses that directly address the federal regulatory framework and how a given design case fits into that framework. Within these analyses, we define that pertinent federal regulations that apply to the given design case, what adjustments could be made to meet the federal regulations, and finally what adjustments may be required to meet best available control technology requirements, which are an upper bound. The state-level regulations vary by state, which makes a state-specific assessment difficult to perform unless we are assessing a specific case study. We have plans in FY 2018 to begin looking at a case study which will entail state-level regulations. Successful application of our work would include design cases that incorporate mitigation options as defined by our work as well as collaborating with biorefinery designers working on the ground. As for other agricultural air-quality models, FPEAM fills the gap in that we assess the major emissions sources related to agricultural production. We do not tie directly into any specific agricultural air-quality models, though we have met with researchers from USDA and presented FPEAM to them.

  3. Whether there were any surprising findings, as a result of the more sophisticated modeling, relative to what was expected at the beginning. We aim to perform more sophisticated modeling and case studies as we move forward. We are objective in our approach and if we come across findings that are contradictory or surprising we will investigate and understand the insights thoroughly.

  4. Greater emphasis on how deliverables may be used. We are still in the development phase of FPEAM as a tool. As we proceed through this Fiscal Year and next (FY 2018), we anticipate having beta testers of the tool as well as conducting outreach efforts to local and state agencies as well as academia. Specific users already identified include the EPA, California Air Resources Board, and the University of Minnesota. We hope to expand that list of users as we proceed and will tailor the tool based on feedback from beta testers.

  5. Why the project did not consider processing and combustion emissions, which are critical to understanding the overall life cycle impact. This project has progressed in a linear fashion moving down the supply chain from feedstock through fuel production. We have not taken on the end-use phase of the life cycle because the needs of BETO and budget have not allowed for a thorough exploration of this phase of the life cycle. That said, one of our long-range goals has been to conduct a full supply chain assessment for a given fuel pathway.

  6. Milestones, decision points, and challenges were not provided in sufficient detail. This is good feedback and we will work to address these items more clearly in future presentations.

  7. Spend some time refining the FPEAM model so that it has a user-friendly format that can be used by others. We want to make the FPEAM tool as useful as possible. We will be following standard software development and release protocols as we move forward. This includes a beta and alpha testing phase prior to release.

  8. Ensure that this framework is either directly or in complement with other modeling. We will be working with stakeholders, including other modelers, to seek feedback on our work. Through this effort we will strive to ensure cross-model compatibility at least in terms of inputs and outputs.

NREL INTERNATIONAL SUSTAINABILITY

(WBS #: 4.2.1.31)

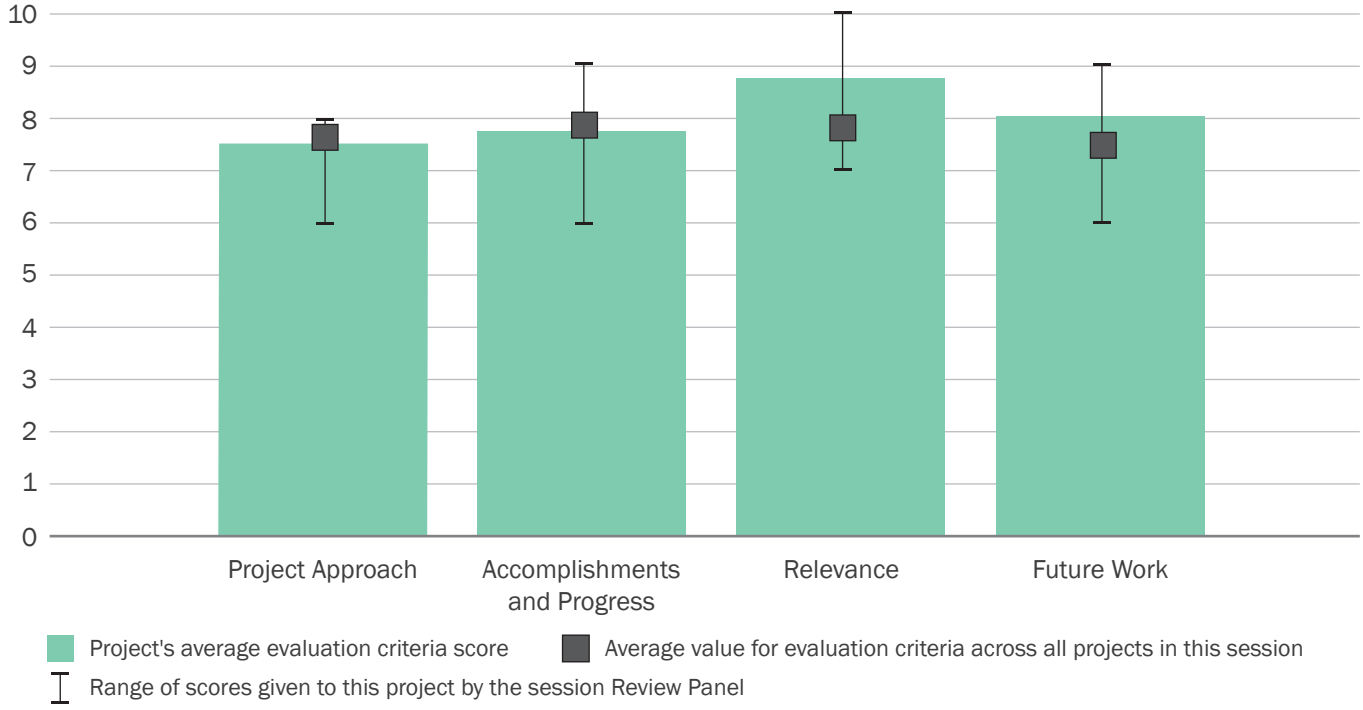
Project Description

The project analyzes and synthesizes key global bioenergy/bioeconomy activities to identify opportunities and address challenges to stimulate the U.S. bioeconomy and improve sustainability. Partnering in bioenergy and sustainability assessment is conducted for U.S. government/BETO United Nations– or IEA-related multilateral initiatives, updated periodically. Under this task, the project team designed a systematic process to evaluate tools to assess the environmental, economic, and social sustainability of various biomass and bioenergy systems through collaboration with the IEA Bioenergy community The team is also assessing voluntary sustainability standards (VSS) and started to regionalize the Roundtable on Sustainable Biomaterials (RSB), a leading VSS. RSB drafted the application of its principles and criteria to the United States and provided a draft corn stover removal protocol for U.S. conditions, considering prior U.S. information. The PI addressed a gap in modeling and energy security and bioenergy for the Scientific Committee on Problems of the Environment (SCOPE) update. This project's relevance includes the following: (1) engaging international partners on improving sustainability models and metrics and expanding the knowledge base for sustainability analysis, which is critical for the success of an advanced bioenergy industry,

Recipient:	National Renewable Energy Laboratory
Principal Investigator:	Helena Chum
Project Dates:	10/1/2013–9/30/2019
Project Category:	Ongoing
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$270,000
DOE Funding FY 2015:	$352,000
DOE Funding FY 2016:	$200,000
DOE Funding FY 2017:	$300,000

Weighted Project Score: 8.0

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



and (2) work to decrease barriers to international trade from the United States. The task will continue (1) to assess sustainability evaluation tools in various bioenergy and bioeconomy contexts, (2) to assess VSS, and (3) to partner with ORNL, ANL, and INL on sustainability of integrated systems.

Overall Impressions

- This project strives to engage with international partners to improve sustainability models and metrics and expand the knowledge base for sustainability analysis critical to the success of an advanced bioenergy industry. Dr. Chum's vast network and participation in international forums helps to highlight all of the work sponsored by BETO. It also helps to mitigate potential barriers to growth in the bioeconomy by having a seat at the table. The work is highly leveraged and crosscutting. Collaboration is key in a project of this type. This work helps to identify the opportunities and address the challenges necessary to stimulate the U.S. bioeconomy and improve sustainability. The work is primarily a continuation of the activities since the last review. Project activities include improving the sustainability assessments of integrated biobased systems, assessing voluntary sustainability standards, and participating in multilateral bioeconomy assessments. Value from this project comes from its ability to analyze and synthesize key global bioenergy and bioeconomy activities and thereby, identify opportunities and challenges for the expansion of the U.S. bioeconomy and sustainability. In a project of this scope, it is critical to prioritize and select activities that address gaps or where confusion exists. Engaging with key international partners on this work is critical. Future work will be a continuation of the work listed above. Since this project is basically to ensure a scientific U.S. perspective in global discussions, continued communication will be critical. I applaud the efforts around harmonization of models and assumptions to ensure a more apples-to-apples approach. As always, due to limited resources, the work should be focused on the most critical issues. However, it is good to see that the work being done here, like the bioenergy and sustainability paper, is being read and moving the discussion.
- The project appears to play an analytical support role to a variety of ongoing processes. Future work is envisioned, and the process by which decisions are made to pursue discrete tasks under the project was detailed, addressing what would otherwise be my only concern with the project. I was likewise heartened to learn of substantial formalized and informal interaction between BETO project teams working on similar issues (e.g., sustainability).
- It was difficult for me to get a good sense of the objectives and accomplishments of this project. It seems that it has been successful in highlighting U.S. engagement in international sustainability efforts. Its specific achievements in this regard are more nebulous, however.
- This project provides technical expertise and participation in international processes on bioenergy sustainability assessment and is one of the most strategic initiatives in BETO's portfolio. It directly supports the goals of promoting greater understanding of sustainability and providing strategic, science-based communications to drive commercial development of sustainable bioenergy technologies. Participation in international fora is key to ensure alignment of standards at the global level to reduce trade barriers as well as ensure BETO's portfolio of research and expertise has a two-way channel of communications regarding leading science and best practices. The accomplishments in terms of contributions to high-impact reports and processes under IPCC, IEA, and SCOPE are among the most impressive in the BETO portfolio. The support of processes and assessment in Brazil is also strategically important. Finally, the participation in the voluntary RSB standard could also have a high impact.

  The top challenge to maximize strategic value is to identify the most critical issues of alignment/misalignment emerging from the international discussions and to ensure strong channels of com-

munications to and from BETO's broader portfolio of initiatives. It would be particularly important to establish a regular communications channel from each of the other major BETO projects with this project to ensure best practices are channeled to and from the international community.

PI Response to Reviewer Comments

- The PI and team thank the reviewers for the insightful comments, suggestions, and recognition of the value of the high-level publications that resulted from activities we performed. The reviewers summarized very well the difficulty of assessing the broad fields and linking to and from the communities (United States and international) the major gaps of understanding sustainability of biomass, bioenergy, and products systems. Many gaps result from lack of understanding of the more distributed U.S. government system compared to the majority of the European countries. In addition, many scientific and social science communities involved are not aware of each other's activities and their work impact on integrated assessment models used to assess bioenergy as part of agriculture, forestry, and waste management on sustainable development including climate. We are hoping that through the Bioenergy KDF's sustainability page our key information will be found by U.S. participants, international collaborators, and others including VSS and BETO, and through the links to other national and multilateral programs. ORNL and NREL are working on this draft webpage as a potential for dissemination of information and a source of comments from the international community as well. ANL, INL, PNNL will review the proposed page and contribute in future if this go/no go milestone receives the go ahead to continue. For GHG emissions, looking at fossil energy use and other metrics, there are accessible tools to allow for harmonization of LCA efforts to directly attribute inputs and outputs within the analysis boundaries. Going outside these boundaries to understand emissions over time, space, economic sectors (consequential analyses), and policy implications, methodologies have not reached convergent results and research continues. For the environmental and social indicators, the level of agreement is not the same with significant differences between the United States and European countries. Tools for some components are addressed by the program. Our future work will test multiple approaches and show alignment/misalignment in methodologies used.

  The United States has multiple data sources and methodologies to evaluate the bioeconomy. We will follow EPA's environmentally extended methodology on an economic input and output basis (by ingwersen.wesley@epa.gov and collaborators). USDA has a different database and open access tool for LCA rich in biomass production data. The harmonization analysis shows that it is important for the actual data for LCAs to come from the country where the resources are used to make the products and fuels. Additionally, many countries lack data on ecological impacts. Improved harmonization will be more feasible in the future as more countries develop their own data sources (e.g., detailed inventories of GHG emissions and removals). The data need to be obtained and this is a very strong aspect of BETO through ORNL, ANL, INL, and collaborators' projects, including the USDA, and is already embedded into the efforts of the current IEA Bioenergy Intertask.

  Specific activities in the reporting period (October 2016–April 2017) include the following: (1) RSB North American regionalization (project's first year); (2) Brazilian work (first year of the Brazilian work and second of the U.S. work); (3) understanding the various ongoing multilateral programs and activities, in this case resulting from agreement on the Agenda 2030 of the United Nations on Sustainable Development Goals (August 2016) and the Paris Agreement on climate (November 2016) (first year of funding); (4) linkages between models (previous and first year funding); (5) SCOPE update (new); (6) standards alignment—time did not permit us to show the mapping of efforts.

FORECASTING WATER QUALITY AND BIODIVERSITY

(WBS #: 4.2.1.40)

Recipient:	Oak Ridge National Laboratory
Principal Investigator:	Yetta Jager
Project Dates:	10/1/2010–9/30/2017
Project Category:	Ongoing
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$200,000
DOE Funding FY 2015:	$300,000
DOE Funding FY 2016:	$350,000
DOE Funding FY 2017:	$400,000

Project Description

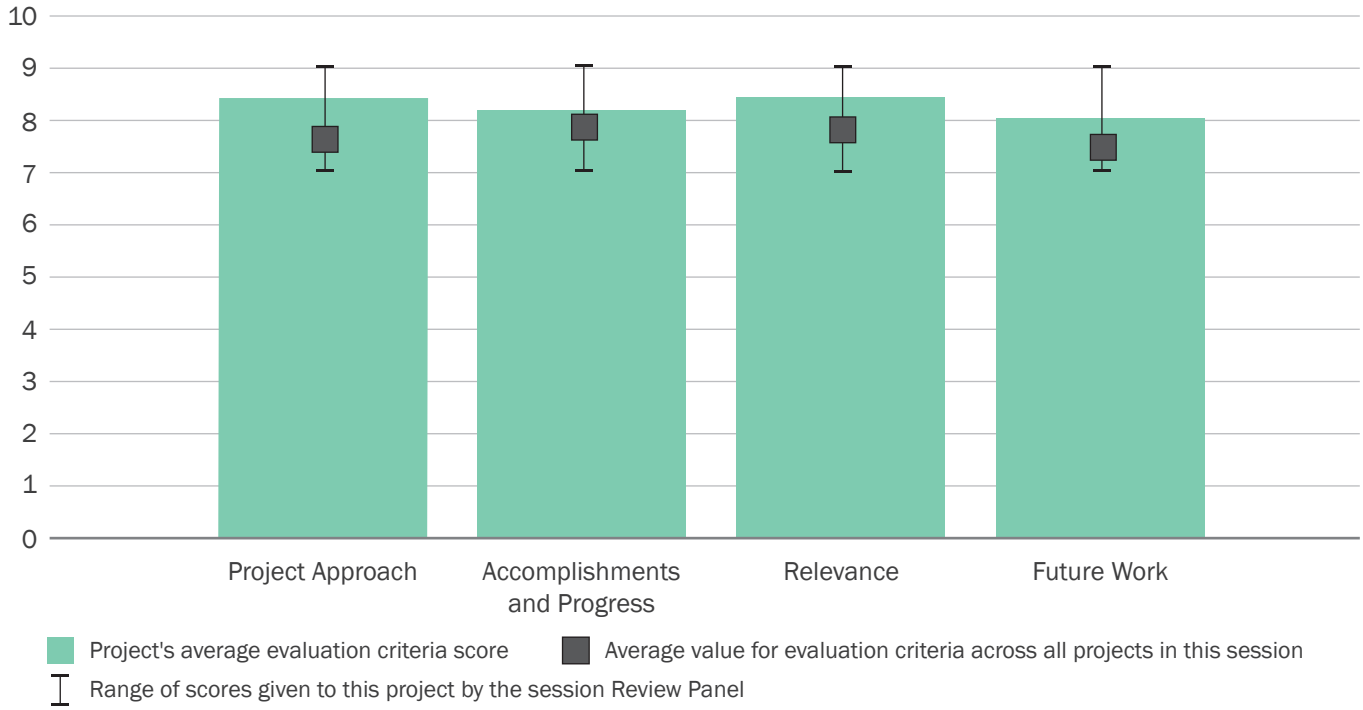
The emerging bioeconomy has raised public concerns about adverse effects on biodiversity and water quality. This project previously demonstrated benefits of perennial feedstocks in two tributary basins of the Mississippi River in a joint effort to examine effects on Gulf hypoxia. We participate in Hypoxia Taskforce meetings and recently co-organized an exploratory workshop on 'Bioenergy Solutions to Gulf Hypoxia' to highlight the economic value of improving water through advanced bioenergy. This project also led two chapters of *BT16* volume 2. Conservation practices made it possible to increase yields with lower effects on water quality and changes in avian richness were estimated under Billion-ton assumptions. We are developing models to identify strategies for co-producing wildlife and biomass in two different production systems. In the Pacific Northwest, forest thinning may reduce wildfire, produce biomass, and restore listed salmonids. In Iowa, crop management protocols will be designed for USDA lands designated for pheasant recovery.

Overall Impressions

- This is an ambitious project designed to address the concerns that a growing bioeconomy places on water quality and biodiversity. The project seeks to

Weighted Project Score: 8.3

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



collect large-scale data and develop the tools necessary to optimize for sustainability in an agricultural system with large-scale bioenergy crop production by linking the management of biomass feedstocks to the consequences for wildlife and downstream water quality at different spatial scales. Key accomplishments include using the team's modeling tools to contribute to two chapters in *BT16* volume 2. The first looked at simulated water quality and yield responses with different conservation practices for a landscape consistent with *BT16* assumptions in two river basins with different feedstock signatures, and the second produced national-scale estimates of bird richness and range shifts under *BT16* scenarios. Both of these efforts required extensive data collection and analysis including scaling down county-level data to meet their watershed requirements. The project addresses a number of BETO goals, but more importantly, helps promote a better understanding of landscape design approaches that enable increased bioenergy production while still providing clean water and enhanced ecosystem and social benefits. As we move to increased biofuel production, it is important to understand and promote the positive economic and environmental effects of biofuels production activities while reducing the potential negative impacts. Sound science and best management practices resulting in win/win opportunities for water quality improvements while increasing the potential feedstock supply will help to drive the acceptance and the profitability of large-scale bioenergy production. An example of this can be seen with the forest thinning project which seeks to supply biomass while reducing wildfire and promoting better salmon habitat.

Moving forward, the work to quantify bioenergy influences on nutrient exports and, in particular, addressing solutions to the hypoxia in the Gulf will be important. The work on the thinning of western forest to promote biofuel and salmon production is another good example of using the tools developed to address specific issues that could have large potential impacts. It would be good to understand how these specific examples could be generalized and used to identify positive management practices on a wider national scale. Efforts to use the information generated from these projects to influence or identify landscape design guidelines for improving water quality and biodiversity under a variety of landscapes could provide insight into the impacts of producing bioenergy crops at a larger scale. I would encourage the project team to look at the lessons learned to identify similarities and differences that could be applied more broadly.

- Generally, the project provided well-documented evidence to support accomplishments and future work. I appreciate that the PIs placed the work and success factors in the context of major challenges, making it easier to see the contributions of the project.
- This presentation summarized an impressive array of good work. The concern I have, however, is that the project's results must be seen in the right context. While it may be that the production of biomass crops results in lower water pollution than would be generated by the dedication of the same lands to conventional crops, those conventional crops would, by and large, be produced somewhere else. Thus, water pollution issues associated with their growth would be transferred, not necessarily obviated. It is unreasonable to expect one project to deal with all of these complicated issues, but it is important to (1) present results with reasonable caveats and (2) think about how the findings of this project might be integrated with higher-level modeling of integrated food and biomass production.

  An interesting aspect of this project is how it integrates with other work described in the BETO portfolio, including the effects of fire suppression on salmonid populations in the Northwest and the striking finding on Slide 20 that the last bit of land

pressed into biomass supply contributes astronomical (comparatively, at least) quantities of reactive nitrogen loading. Documentation of this result as a general finding across landscapes and regions could inform important conservation and production decisions.

- This project appears a model of how technically innovative analysis of sustainability can be used for practical applications to illustrate trade-offs, as well as win/win opportunities. The project also seems a model of a project that is well integrated and nested with other projects in the portfolio and to have a good approach for dissemination and communication of results as well as practical policy-relevant applications in support of stakeholder needs.

  Close coordination with potential users within and outside government will be critical to maximize the potential. In terms of success factors, the project would do well to consider a goal in terms of practical application in one of the other projects in addition to technical accomplishments.

  It would be beneficial to ensure coordination between this project and the ORNL project to define sustainability metrics for the portfolio (#4.2.2.40) to ensure synergies and provide a potential test case. It would also be helpful to spell out connection to other projects, including the Antares-led project (#4.2.2.60) which has a focus on conservation reserve programs and ORNL's project on forest restoration (#4.1.1.52).

- This project has been successful in providing results for water quality and biodiversity outcomes associated with biofuel production. These are two key impact categories for understanding the sustainability of biofuel feedstock production systems.

  While it wasn't discussed explicitly in the presentation, there would appear to be a synergy between the watershed water quality modeling and landscape biodiversity modeling occurring in this project. Moving forward, it would be helpful to more clearly define the synergies, data flows, communication, and transfer of methods between the two aspects of the project.

  The production of two chapters for *BT16* volume 2 has served to coordinate efforts in this project around clear questions and deliverables. The report clearly plays an important role in bringing together a wide range of BETO efforts into a single coordinated product.

  The models of species biodiversity offer a perspective not provided by other projects in the portfolio we reviewed. The performance statistics for the species biodiversity models presented in Chapter 10 of *BT16* volume 2 demonstrate the promise of the models. However, the findings of Chapter 10 show that it would be interesting to apply the models to a wider variety of situations. The authors do not find a significant benefit for strip harvest and indicate that the findings might be different for a scenario where harvesting leaves patches with a higher area to perimeter proportion. The authors also caveat their findings with a number of simplifying assumptions about the behavior and life cycles of the taxa considered and the habitat provided by the biofuel feedstocks (e.g., Miscanthus is assumed to not provide habitat).

  Moving forward, it would be beneficial to focus on improving the biodiversity models for the purpose of screening biofuel feedstocks for their effects on biodiversity. The results of the work so far are promising. The authors offer a few suggestions of how models could be improved in terms of increased inclusion of taxa and improvement in assumptions regarding the crops, landscapes, and animal behavior. In terms of priority, it would appear that refining the models for the already selected set of taxa and getting to the point where the models are able to clearly distinguish crops and management practices that have significant benefits for biodi-

versity should take priority over adding new taxa. Once the models are robust and promising crops and management practices have been identified, it would make sense to add taxa to screen for potential trade-offs across species. The work should have a go/no go decision point related to demonstrating identification of crops and management practices that result in significant differences in species diversity.

PI Response to Reviewer Comments

- In response to Reviewer 2, we agree that the supply curve result is a striking finding, and we hope to elevate our collaboration with ORNL Resource Assessment to publish these results.

  Several reviewers have mentioned a need to generalize from the more local- or watershed-scale biodiversity task/studies to increase the study's relevance.

COLLABORATIONS TO ASSESS LAND EFFECTS OF BIOENERGY

(WBS #: 4.2.1.41)

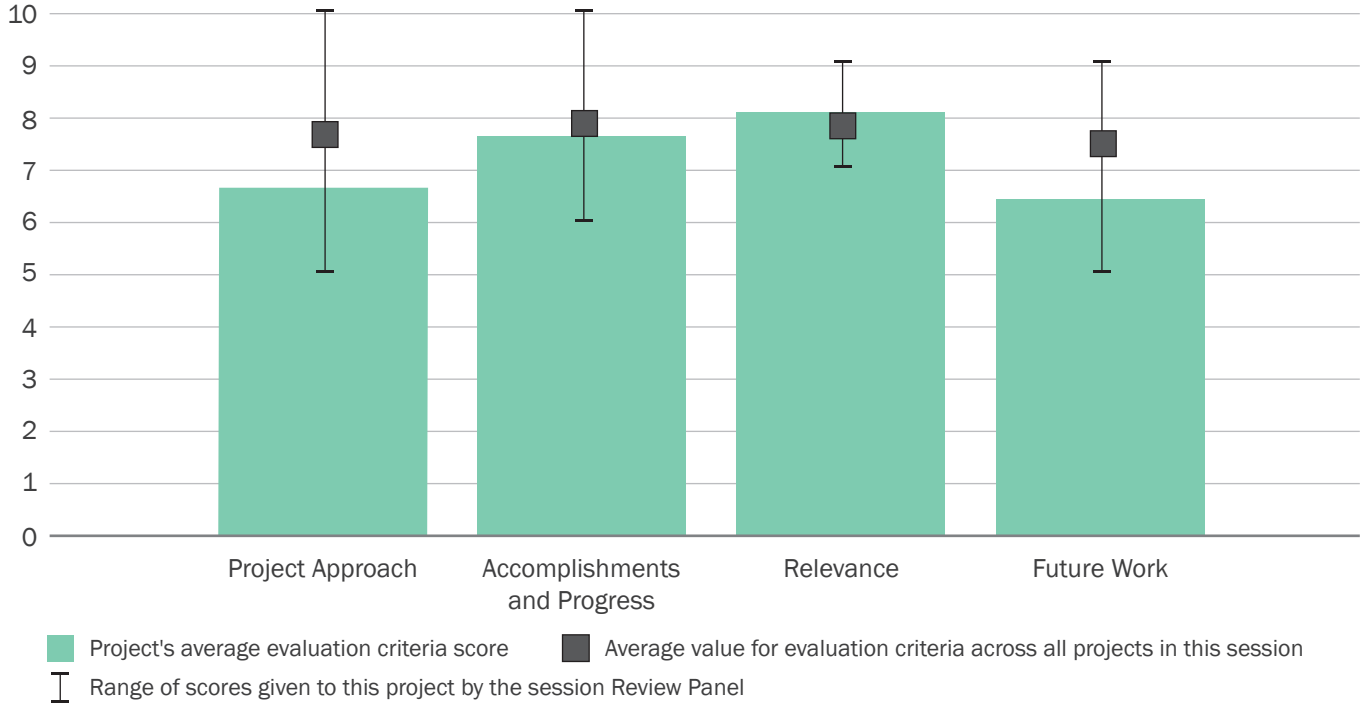
Recipient:	Oak Ridge National Laboratory
Principal Investigator:	Keith Kline
Project Dates:	10/1/2013–9/30/2017
Project Category:	Ongoing
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$250,000
DOE Funding FY 2015:	$200,000
DOE Funding FY 2016:	$250,000
DOE Funding FY 2017:	$350,000

Project Description

LUC issues are formidable and contentious barriers to an expanding biobased economy. The project objective is to transform the LUC bioenergy debate from its focus on concerns to one targeting opportunities to improve land management. As part of the project, a new LUC paradigm will be developed and supported through collaborative research with IEA Bioenergy, Research Collaboration Networks at the National Science Foundation), and other agencies and programs. Publications, and strategic international communications will be leveraged to support U.S. goals for growth in value-added biobased production, jobs, and secure, domestic energy. The expected outcomes include (1) better practices to consistently assess LUC; (2) standardized definitions and methods for reference case and land/management; (3) more-efficient compliance with market sustainability requirements; (4) reduced barriers to trade and investment; (5) and mitigated social and environmental concerns driven by LUC assumptions (e.g., food-security, biodiversity, deforestation, and GHG emissions). Publications, presentations, and online materials will help DOE quantify the benefits to be derived from a U.S. bioeconomy and support BETO goals to (1) "validate

Weighted Project Score: 7.2

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



case studies of feedstock production systems [and]… identify strategies to translate beneficial practices into broader applications," and (2) "quantify and clearly communicate the environmental and socio-economic benefits of emerging advanced bioenergy pathways."

Overall Impressions

- The goal of this project is to transform the LUC bioenergy debate from its focus on concerns to one targeting opportunities to improve land management for food and energy security as well as other social and environmental benefits. This shift in critical thinking highlights the value of this project which takes a scientific approach to impacting decision making. The project is a great example of collaboration across a wide network of stakeholders and strategic partners. The work leverages other BETO research and places a high priority on outreach and publications in an attempt to increase international awareness of sound, science-based messaging. Since the last review, the team has produced 21 publications, including a chapter in *BT16* volume 2 on LUC, made 38 presentations, and successfully influenced the publication of the ASTM International and International Organization for Standardization international standards. It is great to see this type of outreach since it is critical to ensure that the standards set are in line with U.S. interests.

  I consider the work on LUC to be of particular importance. Incomplete information and uncertainties around the LUC issue have the potential to undermine the acceptance of not just bioenergy but all biobased materials. This project excels in forming strategic partnerships and using a science-based approach to generate more reliable LUC assessments, thereby switching the thinking from a negative to an enabler. This work is making a difference. It strives to answer critical questions impacting the sustainable development of the bioenergy industry and the bioeconomy as a whole and works to ensure that the information generated by the project is made available to the global community. Future work will include joint research around science-based approaches to promote beneficial LUC that are cost-effective, practical, and shift the debate to improving land management for food and energy security. I think it is important when tackling this work that the team broadens its focus to include bioproducts and other aspects of the bioeconomy and not restrict its work to biofuels only. It is also critical when influencing policy to get the incentives right (e.g., carbon tax). Expanding this work to look not just at standards but policy implications could be beneficial.

- This project has achieved substantial progress and has several high-level accomplishments to point to. As a project that is intended to be wide ranging and responsive, I challenge the project team to more clearly communicate how analytical or support needs will be identified, what the process is for selecting particular project activities, and what the approach will be for implementing them.

- There is an underlying ambiguity in this project between whether it is intended to do research or to promote research that has been done. Either might be a worthy goal, though if it is the latter, it is important that the research results be chosen carefully and presented without bias.

- The project's stated aim is to "transform the debate" on LUC and bioenergy from focus on concerns to targeting economic and environmental opportunities. While the work appears scientifically grounded and impactful, the framing seems to assume rather than deriving the conclusions and focusing on the "debate" instead of changing the ultimate policies and impacts. This seems to undermine the scientific credibility of the endeavor. A recommended alternative framing of the goal would be to conduct research to build the rigorous evidence base on the actual land-use impacts of bioenergy policies, under different approaches, and to promote policy recom-

mendations to help ensure that bioenergy policies deliver the anticipated win/win.

The project has a large number of publications and reports as well as outreach presentations in a variety of fora. The project also has a very long list of proposed future plans. While impressive, a more focused and prioritized research agenda on high-impact publications, including potentially a high-profile synthesis paper, would likely ensure greatest chances of success.

- The topic of LUC is a relevant one for bioenergy systems and this project demonstrates that the project team is highly connected to international efforts in this area. What is not clear from the presentation is the research approach. It would be nice to see the specific research questions being addressed, the approaches planned, and the metrics for success. As it is, the project appears as a collection of opportunistic efforts and quick response capabilities. For effective management, it would be helpful to focus on key outcomes the project supports and to design the effort to provide outputs that support those outcomes. The project should track metrics for success and in the next review present progress against those metrics.

  As it is, it is easy to see this project is doing a lot, but it is particularly challenging to evaluate the effectiveness or scientific integrity of this project based on the presentation.

PI Response to Reviewer Comments

- We appreciate the comments and plan to implement reviewers' recommendations to
  - Document the selection criteria applied for selecting project activities
  - Consider LUC in the context of 'other aspects of the bioeconomy' beyond biofuels
  - Increase focus on strategic, high-impact collaborations including at least one high-profile research paper
  - Generate credible, science-based analyses to test hypotheses
  - Ensure that results are shared with BETO and other laboratories.

Incorporation of these recommendations in work plans will be reflected by milestones and metrics to facilitate tracking progress. Among the criteria considered to select activities are EERE's high impact, "additionality" (e.g., can we make difference and not duplicate private-sector work?), openness/transparency, enduring economic benefits to the United States, proper role of U.S. government, and addressing strategic priorities.

This is not an "advocacy" project. Rather, we collaborate on research and dissemination of results while consistently advocating for science-based approaches to analyze LUC. We energetically agree on the importance of documenting how research results support (or do not support) clearly defined hypotheses. We will continue to strive to develop and apply the "Causal Analysis Framework" and complementary analyses of empirical data to test hypotheses.[40] Thus, we endorse the recommendations to focus squarely on rigorous research and science-based discovery to generate policy-relevant and actionable results. By involving others in the research discovery process, this project will continue to leverage resources to achieve multiplier effects in terms of research, outreach, and impacts. Here is an example of the evidence of the multiplier effect: DOE and ORNL did not have any press releases on

[40] Rebecca A. Efroymson, Keith L. Kline, Arild Angelsen, Peter H. Verburg, Virginia H. Dale, Johannes W. A. Langeveld, and Allen McBride, "A Causal Analysis Framework for Land-Use Change and the Potential Role of Bioenergy Policy," *Land Use Policy* 59 (2016): 516–527, https://doi.org/10.1016/j.landusepol.2016.09.009.

the food security paper but due to the collaborative nature of the work, other research partners ensured that over 60 different media releases across four continents announced the new publication within 10 days of its release, contributing to a record-setting number of downloads as reported by the journal over the following 6 months (media report available from BETO or PI).

We agree with reviewers that LUC is a global issue which requires engagement of conflicting views to build consensus. It was reassuring to see agreement across a diverse Review Panel regarding the high relevance of this project's research and the progress made to date in addressing stakeholder concerns related to LUC. We acknowledge that the goal statement to "transform the LUC debate" may not be the best choice of words, so we will collaborate with BETO on alternative framing that better reflects reviewer recommendations to (1) build a rigorous evidence base on the actual land impacts of bioenergy policies; (2) develop and communicate recommendations to a wide audience; and (3) help to guide development of a U.S. bioeconomy toward "anticipated win/wins," which represent core goals for our work. Shifting an established global paradigm is a "stretch goal." While it may be beyond our control, we will do our best to achieve results via strategic interventions and persistence. Thank you for your thoughtful contributions to the effort.

CARBON CYCLING, ENVIRONMENTAL & RURAL ECONOMIC IMPACTS OF COLLECTING & PROCESSING SPECIFIC WOODY FEEDSTOCKS IN BIOFUELS

(WBS #: 4.2.1.60)

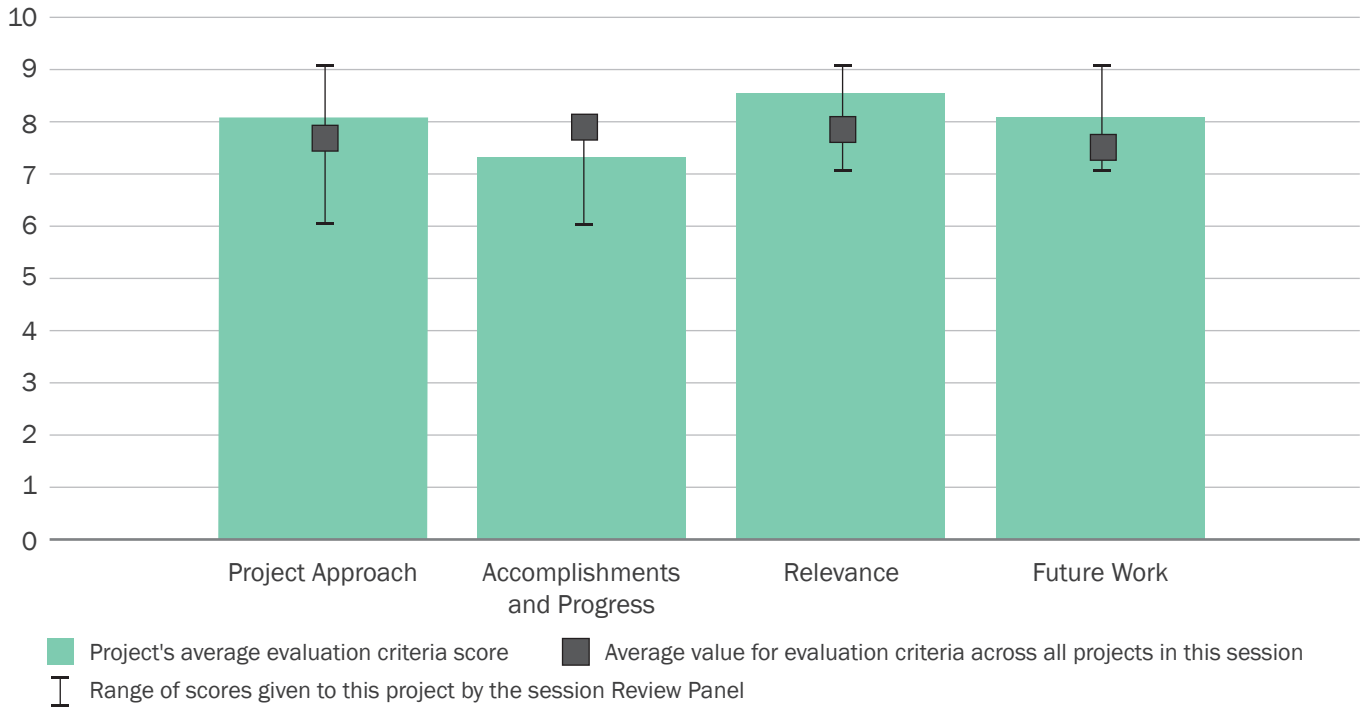
Recipient:	Consortium for Research on Renewable Industrial Materials
Principal Investigator:	Steve Kelley
Project Dates:	8/31/2010–3/31/2018
Project Category:	Ongoing
Project Type:	FY 2009—BRDI: DE-PS36-09G099016
Total DOE Funding:	$1,430,535

Project Description

The project will quantify global warming impacts for regionally specific woody feedstocks from commercial softwood systems and short-rotation woody crops (SRWC) and provide LCA inputs for ANL's GREET team. This work is done in close collaboration with that team to ensure these analyses are consistent with current GREET scenarios. This work includes regionally specific commercial softwoods and SRWC from three U.S. regions (i.e., the Pacific Northwest, Southeast, and Northeast). These woody feedstocks are used as inputs for the DOE thermochemical process model, which has been modified to be sensitive to biomass composition, ash content, and moisture content. The LCA impacts of variations in woody biomass growth rates, chemical properties, and the allocation of woody biomass for durable wood products, paper, and biofuels are being quantified. The environmental burdens will be allocated to durable wood products, paper, and the biorefinery feedstocks. The impact of the extended temporal aspects includes of durable wood products (20–70 years), paper products (2–5 years), and commercial forest rotations (25–80 years),

Weighted Project Score: 7.9

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



their disposal or decay, and the variations in commercial practices between regions. The current demand for commercial durable wood products and the unique role of forests in the minds of the American public means that the sustainability of woody biomass systems attracts more attention than many other biomass sources.

Overall Impressions

- The goal of this project is to understand the carbon flows for woody biomass allocated to durable uses such as wood and paper products versus bioenergy products and evaluate the implications for different forest management systems. Understanding the life cycle impacts is especially difficult given the differences in product life spans. The carbon in durable wood products may be sequestered for many years while the carbon in bioenergy systems may be released immediately. Therefore, understanding the assumptions and uncertainties is critical. The project is highly collaborative and strives to produce data that are consistent with and can be utilized by GREET as well as other BETO projects. The team has made good progress since the last review completing Tasks 1 and 2. Specifically, they have completed life cycle inventories for six biomass production systems and completed the allocation to products pools for two of three systems. Of note is the teams' work on understanding the compositional differences between wood types and updating the model to reflect this. Understanding the compositional differences is very important but leads me to question whether or not the quality (e.g., increased levels of inorganic material) of the wood feedstock would also impact the LCA especially when looking at residues versus purposely grown woody crops. Adding this to the analysis would be beneficial. The team is working closely with ANL to ensure consistency. This is important in dissimilar systems since the assumptions and allocation methodology can have a great effect on the analysis and finding. Allocation of burdens between the various products and co-products is especially difficult due to the uncertainty of use and product life cycle. The outcomes of this project will aid in understanding the sustainability of forest systems and their use for bioenergy. While the direct customer for this work is the GREET model, this work will also be valuable to other teams and will help provide a better understanding of the forest carbon cycle for other BETO program areas. Future work will be to address Tasks 3–5. I would also suggest looking at not just the environmental impacts but the economic impacts as well. For example, not just measuring how much wood residue or thinnings are available but how much can be economically collected and the logistics of collection.
- The hiatus in the progress of this project has meant that it is not as far along as it might have been, and, consequently, it is more difficult to assess its achievements and prospects. As the presenter notes, specifying a counterfactual baseline for the analysis will be essential in assessing what the net economic and environmental consequences will be. My overriding impression is simply that we will have to wait until the project is farther along to better evaluate it, but that the plan for future work provides some basis for optimism.
- This project addresses a critical need to assess the impacts of woody feedstocks. This was a gap in *BT16* volume 2 and a priority for BETO to address. This is a key issue for making the environmental case for alternative woody feedstocks and important for public policy on bioenergy in the United States and worldwide.

  The integration with GREET is particularly valuable but broader dissemination as a standalone product should also be considered, including through the Bioenergy KDF platform.

The discounting approach for temporal impacts is appropriate but sensitivity to alternative discount rates should be considered.

It would also be valuable to contextualize results and the modeling approach with other U.S. and international forestry modeling frameworks (e.g., from the Subregional Timber Supply, Forestry and Agricultural Sector Optimization, and the Global Timber Models).

Characterizing the regional and temporal heterogeneity of results under the "business as usual" and "management" scenarios, accounting for different management practices, species mixes, ecological and climatic regimes (e.g., residue decay rates), will be critical to provide policy-relevant information and show how results depend on timeframe and spatial scales. Creating a flexible tool that allows analysis and visualization of alternative scenarios might be of higher value than generating results for particular assumptions.

- This is an important project for creating LCA and consensus models from experimental and other forest biomass research by presenting in a way that is useful for decision making and providing it through the GREET platform for use by others.

It would be helpful to more clearly lay out the research questions being addressed, specific actions which will be used to answer the questions, and plans for disseminating findings. The plans for future research should be more clearly laid out.

PI Response to Reviewer Comments

We appreciate the reviewers' recognition of the overall importance of the work, the value of the regional approach, the complexity of the systems, need to include uncertainty and the natural variation of the woody biomass, and strength of the collaboration between the Consortium for Research on Renewable Industrial Materials and GREET.

While there are many additional aspects of these complex forest systems and an almost infinite array of alternative counterfactuals, we agree that this initial work will provide a robust foundation for future work by this team and other groups interested in forest systems.

We agree that the inclusion of economic considerations and the additional of visualization tools would be a useful next step, but note that this work is outside the scope and budget of the current project.

BIOMASS PRODUCTION AND NITROGEN RECOVERY

(WBS #: 4.2.2.10)

Recipient:	Argonne National Laboratory
Principal Investigator:	Cristina Negri
Project Dates:	10/1/2010–8/28/2019
Project Category:	Ongoing
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$540,000
DOE Funding FY 2015:	$540,000
DOE Funding FY 2016:	$600,000
DOE Funding FY 2017:	$630,000

Project Description

This project aims to bolster the cost competitiveness of bioenergy through the valuation of ecosystem services produced by bioenergy crops in landscape design. It does so by (1) generating primary data from field experimentation to develop new, engineering-based best practices incorporating bioenergy and conservation and (2) modeling at a small-watershed scale two water quality-enhancing landscape designs, integrating bioenergy with grain crops and conservation. Working at these scales addresses the challenge of understanding local stakeholders' options and needs. Results from the multi-year field study point to a dramatic removal of nitrates in the subsurface in conjunction with an experimental willow buffer, and the watershed scale analysis has shown substantial potential benefits at costs that are competitive with mainstream conservation practices. Stakeholder input is sought through periodic engagement via workshops and field meetings. This project has also provided a framework to evaluate the costs of biomass production and logistics, and the value of ecosystem services generated. This framework will be integrated with LCA and used in the future as a comprehensive blueprint to conceptually scale up to the entire agricultural U.S. agricultural landscape. If successful, this project will show a path toward improving bioenergy penetration and yield in the Corn Belt, with

Weighted Project Score: 8.4

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

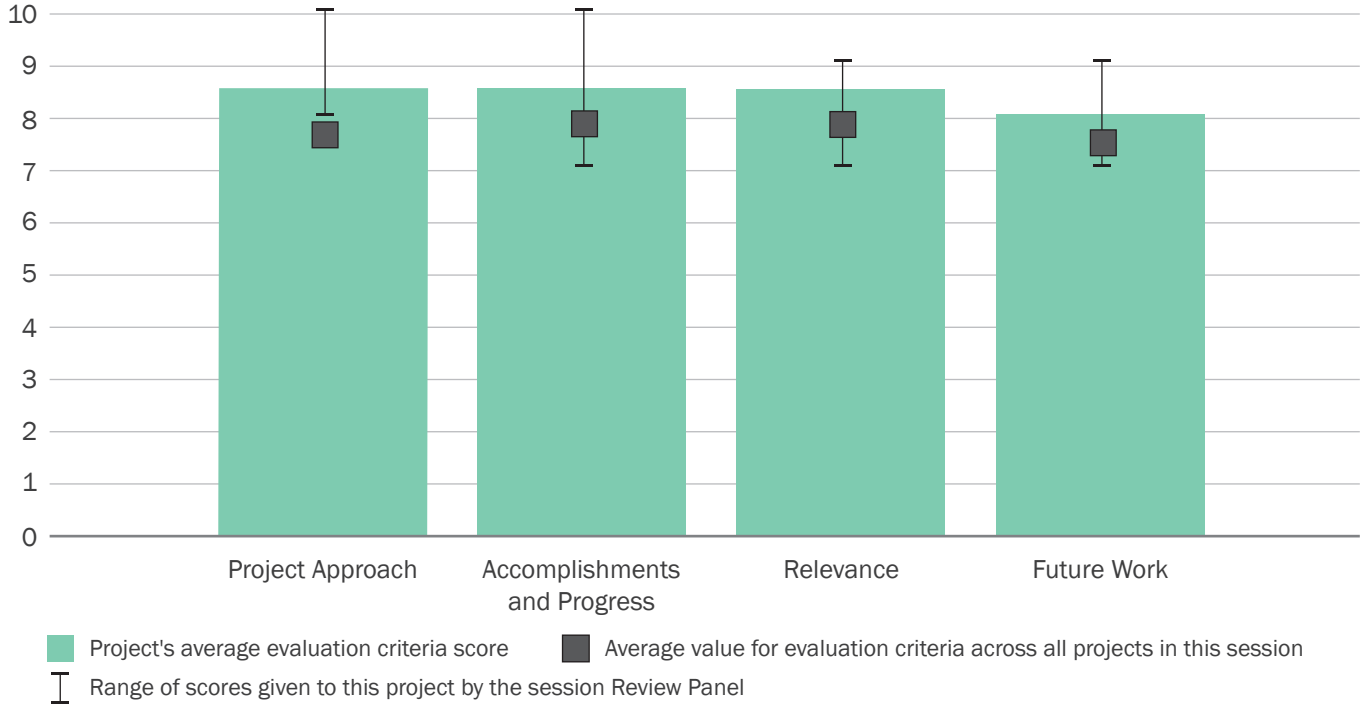


Photo Courtesy of Argonne National Laboratory

concurrent benefits in reducing water quality problems, such as Hypoxia in the Gulf of Mexico.

Overall Impressions

- This project studies how we can, as part of the bioeconomy, optimize the production of biomass while still providing environmental services. This project starts at the farm level and works to scale up lessons learned to the watershed level. An important aspect of this project is providing value to the farmers to encourage them to integrate bioenergy crops in their current systems. The project is well managed and highly collaborative. In a project of this nature, engaging the various stakeholders, particularly the farmers, is critical. Since the last review this project focused on more ecosystem services, developed TEA of production and logistics at the watershed scale, and worked to understand the potential nutrient markets to provide a viable solution to nutrient loss reduction. I am impressed with the amount and type of data collected in this project. I also found it interesting that the team w exceeded its target of a 30% reduction in nitrate concentrations in soil water in 2015. That is why, even though the team found that producing willow was not cost-effective for the farmer, mostly due to high land rents, we need to consider the value things like reducing nitrates and other ecosystem services should have to society as a whole. We should also consider, if providing these services is something we would like to encourage, what kind of incentives would work. It is also important to understand at what point alternative crops become cost-effective on marginal or less productive areas. This project strives to address barriers in sustainability and sustainable feedstock supply while at the same time providing farmers with added value for adopting bioenergy.

The work and goals of the project are certainly relevant with moving the bioeconomy forward while promoting sustainable solutions. I agree with Dr. Negri that bioenergy is neither good nor bad, but that it is how we deploy it that matters. Improved landscape design could produce biomass in a manner that is positive for the environment and bring added value to the farmer. As far as future work, the team plans to continue its field trial through the next harvest cycle, improve on its landscape design, continue to develop the economic framework and analysis, and develop pathways to include bioenergy landscapes in conservation BMPs. It will be important to better understand the cost competitiveness of bioenergy compared to other conservation practices and engage with farmers particularly on lessons learned. Willow was probably not the best choice for this study.

I understand the team's past work and expertise in the area but starting with a crop more familiar to farmers that could still offer environmental benefits may have been more appropriate. However, the team has generated a vast amount of data and learnings which could be used in testing other cropping systems. Also, providing a set of best practices would be a good outcome for this work as would devising tools that could be used by others. Understanding the scale at which these crops need to grow to be both economically and environmentally effective is important. Also, how would cover crops play into this scenario? Are cover crops effective at stabilizing nitrates while also providing biomass?

- All in all, a well-designed and implemented research project. The methodology is appropriate to the questions being asked, experimental design is robust, and external outreach and engagement help to leverage resources and ensure relevant stakeholders are aware of the work.
- I am quite impressed with this project. It was well designed and carefully conducted. While some might see a project with negative results as a less productive use of funds than one that points to a "success story," we need careful, even-handed investigations of hypotheses under consideration. This project provides relevant information for not only its own context, but that may be helpful in designing programs elsewhere.
- The team collected a lot of valuable data. This project would be stronger if experimental data collection and modeling efforts were more closely linked.
- The project focuses on (1) buffer planting of willows around corn fields and has a detailed field-level component to measure yield, nutrient runoff, and other environmental indicators; (2) a watershed-level modeling exercise; and (3) an associated economic analysis. The study demonstrates the potential role of bioenergy crops to provide biomass as well as nutrient reductions and other environmental benefits. This is exactly the type of analysis that BETO requires to achieve its goals of validating landscape design approaches for at least two bioenergy systems that increase land-use efficiency. The project has an excellent set of research and technical partnerships, as well as community engagement effort, and provides a model for other similar studies for assessing environmental and economic performance at different spatial scales.

  The main issue seems to have been the initial choice of the cropping system which was found to be un-economic. A key question is whether sufficient testing and evaluation were conducted to identify the environmentally and economically most promising technology before investing in the major effort to conduct the detailed assessment. A high-priority next step is establishing a pathway for bioenergy landscapes as part of conservation BMPs. A priority for the economic and environmental analysis is to be able to show the benefits and trade-offs relative to other alternatives to deliver biomass, economic benefits, and nutrient reduction (and potentially other environmental services). The study should also focus on demonstrating and communicating a methodology that best establish a replicable model for other studies.
- Field studies such as this one are important for providing data that can be used in models that extrapolate the results after the project is completed. Moving forward, it is important to consider how the results of this project will be used in order to ensure the data collected and disseminated are as useful as possible. It would be helpful for the project team to demonstrate stronger connections to the other techno-economic and environmental analyses occurring in BETO.

PI Response to Reviewer Comments

- While some might see a project with negative results as a less productive use of funds than one that points to a "success story," we need careful, even-handed investigations of hypotheses under consideration. The main issue seems to have been the initial choice of the cropping system, which was found to be un-economic. We do not see our results as negative, and simply changing the crop system (technology) may not have changed the profitability outcome. Conversely, our work examines a different economic framework that monetizes the production of biomass and favorable, by design, environmental services (which we successfully proved), which are the two outcomes that the landscape design mode was set to obtain.

We hypothesized that landscape design plantings could be costlier than business as usual (BAU) cropping because of increased distances traveled by equipment and our results showed that BAU willow cropping systems, switchgrass, and often even corn itself, would not provide profitable margins from selling the crop biomass alone under these conditions. In some cases, however, the landscape design case would be better than BAU because of lower fertilizer costs and optimized space utilization. We are providing a value proposition for farmers and for society. In other words, our work seeks to answer the question: Would the environmental benefits, if monetized, be a useful way to bolster the profitability of bioenergy in the Midwest while addressing the societal problem of addressing water quality problems associated with corn cropping? As one reviewer correctly stated, the research community needs to determine the societal value of nutrient reduction.

It would be helpful for the project team to demonstrate stronger connections to the other techno-economic and environmental Analysis occurring in BETO. We have already started the integration with LCA and look forward to working with other PIs as we scale up the model.

Willow was probably not the best choice for this study. Starting with a crop more familiar to farmers that could still offer environmental benefits may have been more appropriate. The system tested in this field study can be described as an example of mixed cropping or agroforestry, as it involves a woody crop. Agroforestry practices have been developed and deployed nationwide for all areas where agriculture could be better managed with buffers, windbreaks, and other landscape features. While less familiar to farmers than grasses, we did not encounter particular resistance to willows and farmers have anecdotally been receptive to most crops whose biomass would have a viable market.

The study should also focus on demonstrating and communicating a methodology that best establish a replicable model for other studies. This is planned for FY 2018 and FY 2019, when we will have all the physical models, LCA, and TEA elements of the broader framework available and we will have had the opportunity of testing an improved design. We are also working toward a coordination of existing field sites that have similar or compatible aims to collaborate on meta-analyses, which would be important for larger scale model validation efforts.

This project would be stronger if experimental data collection and modeling efforts were more closely linked. While the field study only analyzes the willow/corn system, modeling includes willow, switchgrass, and prairie grasses as data availability allows. The field study has contributed some of its data to the models, but more importantly an assessment of the soil conditions that would be of interest in targeting underproductive or marginal subfield portions. The field site has several marginality conditions that were used for the watershed study. As mentioned before, watershed models need to be validated by more than one field site, but our work provides a solid foundation for future additional field sites.

We thank the reviewers for their positive comments.

BIOENERGY SUSTAINABILITY: HOW TO DEFINE AND MEASURE IT

(WBS #: 4.2.2.40)

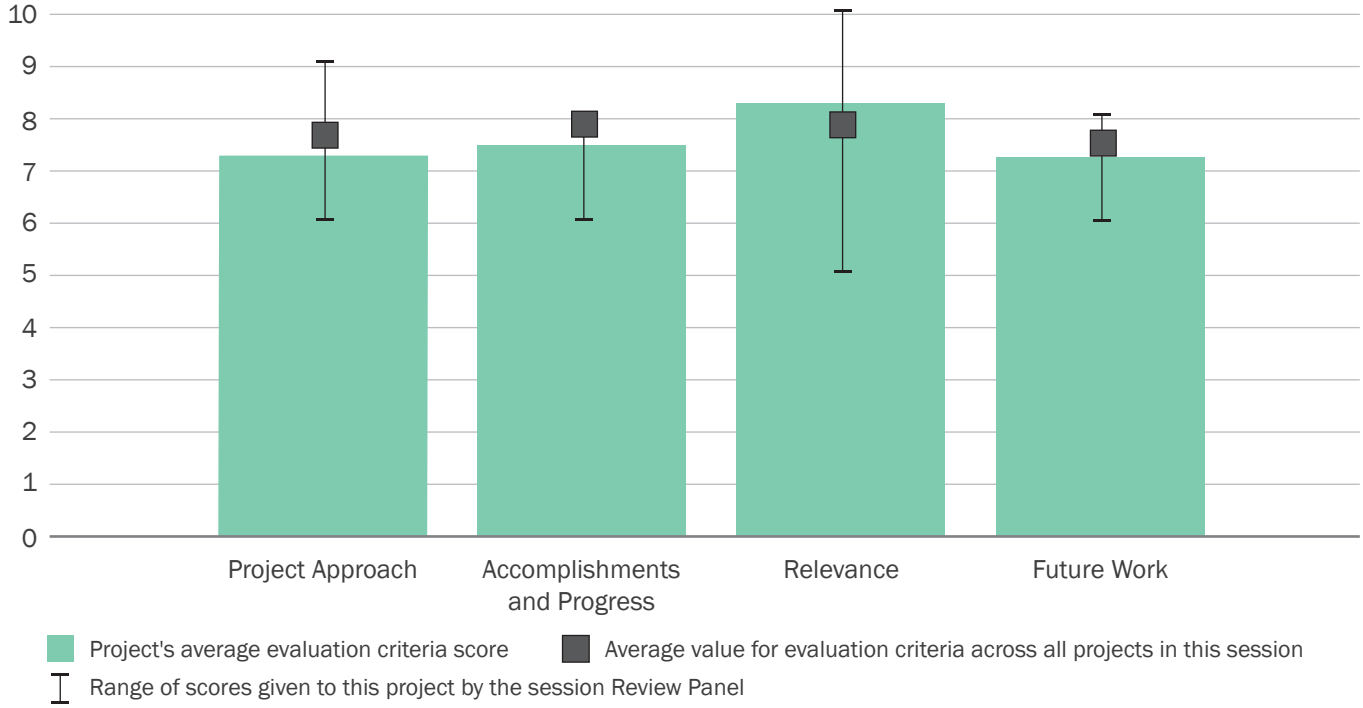
Recipient:	Oak Ridge National Laboratory
Principal Investigator:	Virginia Dale
Project Dates:	10/1/2010–9/30/2018
Project Category:	Ongoing
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$700,000
DOE Funding FY 2015:	$700,000
DOE Funding FY 2016:	$750,000
DOE Funding FY 2017:	$800,000

Project Description

This project defines "bioenergy sustainability" and establishes methodologies for measuring and assessing progress toward a sustainable bioeconomy. Building from our previously proposed indicators and analyses, we focus on (1) developing and testing the overall approach, (2) conducting case studies to validate and further develop our approach (e.g., using switchgrass in east Tennessee, woody residues from the Southeast, and cellulosics in the Midwest), (3) applying the theory of aggregation to bioenergy sustainability, and (4) constructing visualization tools. These efforts have moved from establishment of indicators to determination of baselines and targets for particular contexts, evaluation of indicator values, consideration of trends and potential trade-offs/synergies, and ways to develop and test good management practices. This project addresses the following BETO technical challenges and barriers: (1) scientific consensus on bioenergy sustainability, (2) consistent and science-based messaging on bioenergy sustainability, and (3) implementing indicators and a methodology for evaluating and improving sustainability. The project outcomes are moving the bioenergy

Weighted Project Score: 7.5

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



industry toward more achievable, consistent, comprehensive, cost-effective, and legitimate ways to measure and assess progress toward a sustainable bioeconomy as defined by context-specific indicators and targets and as documented through use of our interactive visualization tool.

Overall Impressions

- This project has a rich history defining what is meant by "sustainability" as well as identifying and developing the metrics by which improvements in sustainability can be quantitatively measured. The last two years have seen the emphasis shift from simply identifying the sustainability metrics to characterizing and understating the relationship between various metrics as well as providing a framework to standardize their use. The project appears to be well managed with regular updates, conference calls, and milestones. This is particularly impressive given the large number and diversity of partners with over 70 partners offering in-kind cost share. Coordinating the various leveraged activities, analyses, and perspectives is a daunting task but seems to be well done. Good progress has been made in meeting project objectives. Technical accomplishments for the project included several case studies looking at growing switchgrass in Tennessee and wood pellets for use in Europe. However, the most significant progress has been around efforts to collectively look at the various sustainability metrics and to ensure sustainability goals are met in the overall ecosystem. This requires normalizing and aggregating data to better understand the overall picture. Normalizing and aggregating a host of different indicators is not easy. The project has accomplished that by setting baselines and quantifying progress around those values. Because weighting the various indicators is often subjective and depends on the unique goals of a particular system, it was appropriate that in this study all 35 metrics were not weighted to give one number. The researchers did however provide the tools necessary so that stakeholders could, according to their needs and interests, aggregate the values in a way that is consistent with their requirements.

  The term "sustainability" was used repeatedly in all of the project reviews as well as during the plenary talks. This indicates how import this work is in serving as a foundation to all of the rest of the work BETO is doing. This project, in particular, helps to provide a level setting by defining what "sustainability" is and how it can be measured. The true value of this project is to get people thinking about a broad umbrella of indicators especially going beyond the traditional environmental indicators and including economic and social impacts as well. It will be important as the project moves forward to enable the use of best practices by providing examples of how these various metrics can be assessed, integrated, and effectively visualized. This includes making sure that all of the appropriate stakeholders are at the table. Since conveying the results, especially when looking at such a wide array of environmental, economic, and social indicators can be daunting, future work includes developing a visualization tool to effectively display progress towards sustainability. It will be important as the project moves forward to enable the use of best practices by providing examples of how these various metrics can be assessed, integrated and effectively visualized. It will continue to be important to get this information disseminated to as broad an audience as possible broadly and transferring the technology to the appropriate stakeholders.

- The project has succeeded in producing a substantial number of deliverables, products, and workshops. Continued effort should be devoted to reporting the contribution of each to the project's strategic objectives. This is a massive undertaking, so it is important to all involved, from stakeholder to funder, to know how all the pieces fit together.

- While a tremendous amount of work has been done on this project, I am concerned that it has not yet delivered on the promise of its title by showing how to define and measure bioenergy sustainability. I was reminded in reviewing this project of a remark by the great economist Robert Solow, "It is hard to talk about 'sustainability' without defining what it is one intends to sustain." It seems that this project is providing numerous examples of different ways that "sustainability" has been defined, and how things that determine it have been measured, but it falls short of providing guidance on the crucial questions of how someone could define and measure "sustainability" in any particular context and how those definitions and measures might need to be modified from one context to another. The publications cited on the mathematics of aggregation begin to explore possibilities, but if this project is to provide results that can be reduced to useful practice, it must take a stand on what principles of aggregation might most usefully be applied, and how.
- This project is centrally important to all of BETO's portfolio and thus needs to be measured to a high standard. While the team has produced a rigorous mathematical framework for multi-criteria analysis, useful visualizations, impressive publications, and interesting applications, the project seems to be falling short of its basic goal of providing greater clarity and rigor over "sustainability" definitions. Rather, it seems to be saying that users can choose their definitions without any constraints, which does not seem ambitious enough for this foundational project. For example, financial sustainability is not a subjective concept and should be measurable over different time horizons. The project team should be less cautious and at least propose some core definitions (e.g., reduction in GHGs as per BETO's goals and/or financial sustainability) and provide a clear set of answers via the evaluations even if users can also adjust the definitions based on alternative definitions. Otherwise, the project risks missing out on its potential relevance.
- This is an important project that closely relates to the goals of the A&S platform. It is struggling to address very worthwhile questions. Moving forward, it would be helpful for this project to more clearly address (1) how the framework developed will be extended to future biofuel systems (at a reasonable cost) and (2) how the approach contributes to our ability to perform streamlined and rigorous analyses of other biofuel systems.

  The creation of "product category rules" for biofuel feedstock types would be an interesting approach moving forward.

  It would also be helpful if this project clearly answered the following questions: (1) What metrics are most important to track for biofuel feedstock systems, and (2) how should these metrics be calculated?

  Finally, it would be useful to consider how the project could support making data available for the analysis of future biofuel systems and/or how could data be brought together from disparate sources to support a comprehensive sustainability assessment of biofuel feedstock production systems?

PI Response to Reviewer Comments

- To assess progress toward a sustainable bioeconomy and provide clarity and rigor in context-specific sustainability definitions, our ORNL team developed an approach to assess progress toward a sustainable bioeconomy. The approach has 6 steps.
  - The scope of the assessment is established based on the particular context, options, and stakeholders' concerns.
  - Indicators that pertain to the objective of making progress toward sustainable bioenergy are selected and prioritized.

- Baselines and targets are determined for each indicator.
- The indicator values are collected and evaluated.
- Trends and trade-offs in the indicator set are analyzed.
- Good practices for the activity are developed and evaluated.

In the effort that preceded the current project, ORNL reviewed the vast literature on environmental and socioeconomic indicators and approaches to characterize progress toward bioenergy sustainability. Based on that review, and in consultation with diverse experts, we selected 12 categories that contain 35 indicators.

The current project is evaluating the six-step approach and, in particular, the 35 indicators via three case studies. We reported on (1) the completed work on switchgrass in Tennessee, (2) the first three steps of analysis of production of wood pellets in the Southeast, and (3) the initial phase of a case involving cellulosic-based energy in Iowa (which was presented by WBS 4.2.2.60).

For the switchgrass case, ORNL worked with colleagues supported by USDA. Information was collected for indicators in all 12 categories. ORNL used that information to proceed through the six-step approach and determined appropriate practices for production of ethanol using switchgrass in east Tennessee. This analysis included multi-attribute decision support systems that illustrated the potential for benefits to be achieved. This case demonstrated the benefits for switchgrass and was a test of the overall approach. We are also quantifying the costs and benefits of applying an existing bioproducts certification scheme to switchgrass in Tennessee. That analysis will reveal if the scheme covers the diversity of indicators that we have found to be important and if such certification has value to the industry.

For the second case, we have begun applying the six-step approach to production of wood-based pellets in the Southeast. We are focusing on private nonindustrial land, which make up 60% of the timberland ownerships where wood pellets can be produced. Relatively little information exists for these lands. The first steps of the approach require selecting indicators based on the stakeholders' concerns. Hence, we are deploying a survey to private nonindustrial forest landowners to better understand and prioritize their sustainability concerns. To obtain data on some of the indicators, our analysis of FIA data for counties where pellet production has been active revealed few changes in forest conditions during the period when pellet production has occurred. We are also developing a framework to examine effects of wood-based pellets on species of concern and their habitats. Hence, we have made progress on Steps 1, 2 and 3 in this case study.

In addition, we recognize the importance of presenting the information to a diversity of stakeholders. Therefore, we are in the process of developing and testing BioSTAR, the Bioenergy Sustainability Target Assessment Resource visualization tool. This tool presents indicator-specific and aggregated information and will eventually be deployed on the Bioenergy KDF. The aggregation methods employed build from mathematical theory of aggregation as well as multidimensional attribute analysis.

Our future work will be to complete the two case studies and to develop and deploy BioSTAR. Our final synthesis will highlight how the specified indicators and six-step approach can be used to identify best practices for diverse bioproducts.

SHORT-ROTATION WOODY BIOMASS SUSTAINABILITY

(WBS #: 4.2.2.41)

Project Description

Recipient:	Oak Ridge National Laboratory
Principal Investigator:	Natalie Griffiths
Project Dates:	10/1/2013–9/30/2018
Project Category:	Ongoing
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$345,000
DOE Funding FY 2015:	$330,000
DOE Funding FY 2016:	$345,000
DOE Funding FY 2017:	$345,000

Woody biomass is expected to be a dominant bioenergy feedstock in the Southeast; however, environmental effects have not been evaluated. Our project uses a watershed-scale experiment and a distributed watershed modeling approach to evaluate the environmental sustainability (i.e., water, soil, and productivity indicators) of intensive management of pine for bioenergy. Three adjacent watersheds (i.e., two treatment and one reference) in South Carolina were instrumented and baseline data were collected between 2010 and 2012. Next, around 50% of the treatment watersheds were harvested in 2012, planted in 2013, and managed (i.e., multiple herbicide and fertilizer applications) for pine production from 2012 to 2016. Forestry BMPs were followed. Baseline measurements showed that groundwater is the dominant flow path. Nitrate concentrations increased in groundwater (<2 mg nitrogen/L) post treatment, but not in stream water, suggesting BMPs protected surface water quality. Plot-scale measurements suggest no fertilizer or half operational fertilizer treatments can satisfy pine nitrogen demand and minimize leaching. Early pine growth was rapid and around 2 years ahead in development com-

Weighted Project Score: 8.0

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

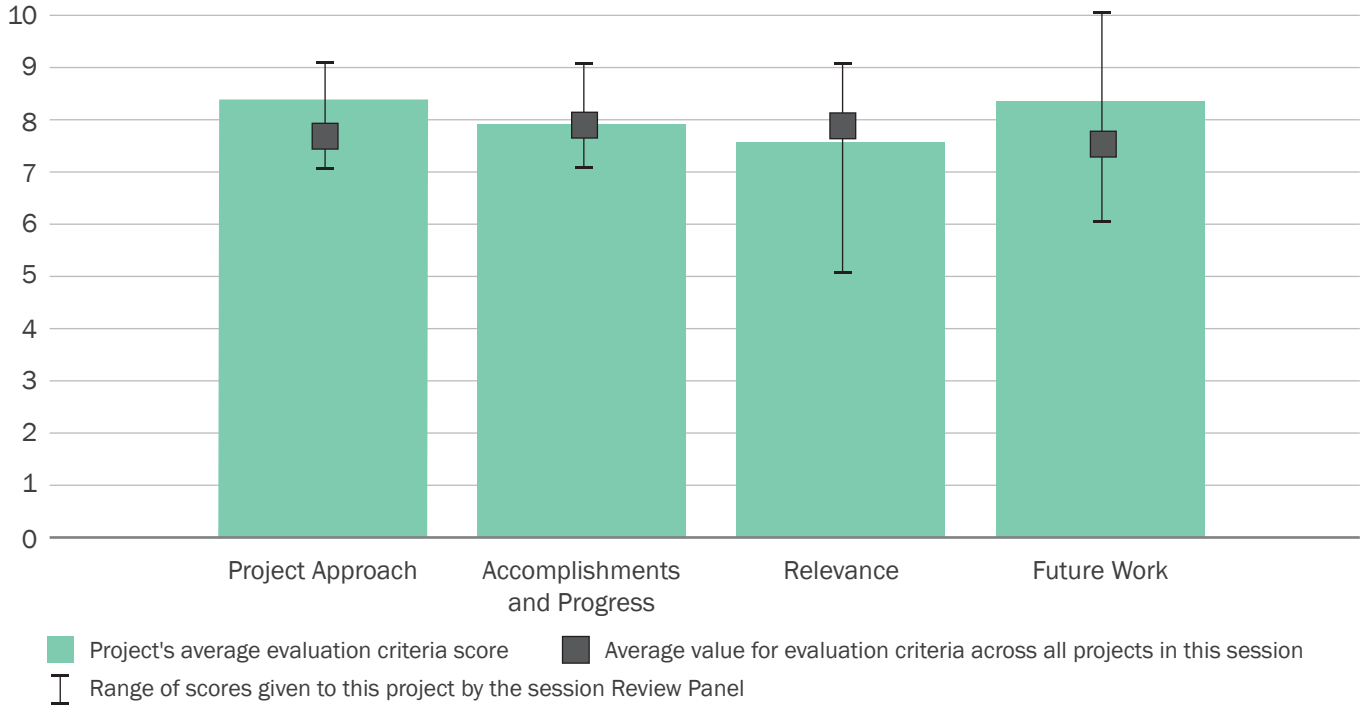


Photo Courtesy of Oak Ridge National Laboratory

pared to standard timber plantations. Forest management scenarios run with standard models (i.e., MIKESHE and SWAT) and the Oregon State University model developed for the Upper Coastal Plain found variable changes in stream flow, depending on model structure. Water, soil, and productivity measurements will continue through 2018 and model application will occur in parallel.

Overall Impressions

- The Southeast has the potential to produce substantial biomass. This project aims to assess the impacts of intensive short-rotation woody crop production on sustainability metrics such as water and soil quality. Its goal is to understand the effectiveness of current forestry practices and apply them more broadly. The project is well managed with frequent meetings, good communication, and extensive collaboration. The use of specific milestones and go/no-go decisions appears to be effective. The work required extensive data collection on each of the three watershed sites. Results thus far show no impacts to stream water quality and no evidence of water limitation. The crops have shown record growth and are two years ahead of standard growth rates. One of the most interesting results is that the no fertilizer and half optimal fertilizer treatments appear to satisfy the nitrogen demand in pine and minimize leaching. Because of this result, the amount of fertilizer used in the study seems to have been excessive. Also, while model development continues, in some cases, significant differences between models will require additional investigation. The overall importance of this work is in demonstrating that biomass production for use in the bioenergy industry can be accomplished while still maintaining or even improving the environmental conditions of water and soil. Ultimately, this work will be used to assess whether current forestry BMPs are adequate to protect water and soils and will inform industry and regulators. While most of the work is site specific, I would love to see this work be broadened for use not just for this particular region but more globally. Because the project is scheduled to wrap up in 2018, I would urge the team to focus on understanding how the data generated could be used to inform BMPs when producing woody biomass in the Southeast. I think the idea of exploring the use of drones for spatially resolved measurements of sustainability indicators is an interesting one. Any time you can take advantage of new technology to further your research goals, it should be explored. I also understand your concern that changing from an open canopy to a closed canopy may present new challenges and impacts that were not observed in the less mature plantation. Finally, would there be any benefit to studying other SRWCs other than loblolly pine in the future?
- The project appears to be designed and managed well. The project likewise appears to be integrated into other, relevant BETO efforts. I challenge the project team to consider how to better integrate external stakeholders into their work or how to better communicate those efforts that are already being undertaken to engage outside constituencies.
- My main concern with this project is in wondering what its incremental contribution is. It is not clear (1) how much is already known about the environmental consequences of loblolly pine plantations in the Southeast and (2) how much such plantations would differ if they were devoted to crops dedicated

to bioenergy than to lumber and/or pulp production. While these questions seem to have been raised in an earlier review, they don't seem to have been definitively answered, and so it is difficult to come to a judgment as to how cost-effective this line of research is for informing policy.

- There were a lot of experimental data collected, but model calibration and validation results need to be presented to assess model efficacy and necessity for model enhancements.
- This is a well-executed project to conduct experimental measurements, based on before and after comparison, and modeling of the watershed-level environmental impacts of SRWCs in the Coastal Plains region of the Southeast with a goal of testing whether current BMPs are sufficient to ensure sustainability. Among the BETO projects, this is one of the most practical and relevant to demonstrating the sustainability of a promising bioenergy pathway. This is directly relevant to the goal of providing commercial viability of a pathway that improves land use efficiency. It would be helpful for the researchers to provide more background on the relative importance of the chosen region and silvicultural approach and to what extent the findings are generalizable to the most commercially prevalent or likely SRWC approaches. It would also be helpful to include a broader sustainability and economic assessment to demonstrate the broader relevance of this pathway.
- This project plays an important role in furthering the development of environmental hydrologic models through comparing multiple models and validating against field measurements.

  Moving forward, it is important the PIs consider how the findings of the field measurements could be extrapolated to other systems. Because of the cost of field measurements, it is important that field experiments are designed to yield data which can help understand a wide range of systems.

  Given the shortcomings in "off-the-shelf" models for representing forest systems, it is important to consider how this project could feed back into hydrologic model development information that would help address current shortcomings in the ability to represent forestry systems.

PI Response to Reviewer Comments

Communicating findings/informing BMPs: Each forest-producing state has a water quality forester, and most large timber producing companies are associated with the National Council for Air and Stream Improvement. PI Jackson maintains regular contact with both groups and has communicated results throughout the project. Because of the prevalence of loblolly pine silviculture throughout the Southeast, study results are directly applicable throughout this region. Furthermore, past forest hydrology and BMP research has demonstrated commonality of relevant water quality processes (e.g., importance of bare soils and hydrologic connectivity and the function of riparian buffers) in forest lands in the United States.

Other SRWCs: Loblolly pine is the top candidate for SRWCs in the Southeast. In regions where other SRWCs may dominate (e.g., poplar in the Pacific Northwest), related watershed-scale experiments coupled with modeling should be carried out.

SRWC versus conventional forestry: The woody bioenergy feedstock market can be supplied by tops and limbs harvested from traditionally managed stands, and by SRWCs grown specifically for this market. If there is a sufficient price for woody feedstocks, SRWC silviculture makes sense because trees are harvested at the point of fastest average growth rate, but before stems reach a quality necessary for pulp or lumber production. From an environmental standpoint, the major difference is greater weed control and fertilization prior to crown closure and more frequent ground disturbance in the SRWC system. The advent of intensive SRWC production for bioenergy raised new forest sustainability and

BMP issues for which the traditional forestry BMPs were not designed. Biomass removal and more frequent rotations create the possibility of increased occurrence of overland flow and transport of contaminants.

Our study seeks to quantify water, soil, and productivity changes associated with SRWC production. This research has not been done at an operational scale and current BMPs are untested. Some studies have investigated effects of harvesting SRWCs, but no watershed scale studies focused on the entire production cycle. Several studies have investigated environmental effects of growing pine for timber, but because of production differences with SRWCs versus timber, it is not known whether these findings are directly applicable to SRWCs.

Informing Hydrologic Models: Our model findings will contribute incrementally to the field of hydrologic modeling and will likely be helpful in modeling forest management scenarios in mixed-use landscapes.

Chosen Region: The Southeast is the dominant U.S. wood production region due to a favorable climate for rapid tree growth and that 90% of forest lands are privately owned. Within the Southeast, loblolly pine accounts for the vast majority of wood production. Widespread technical and human infrastructure exists for the growth, harvest, transport, and processing of pine. In terms of the silvicultural approach used, plot studies have shown that maximum production in loblolly pine is achieved by weed control and annual fertilization. We attempted to mimic those studies operationally by applying multiple herbicide and fertilizer applications. We also chose to push the system in terms of early fertilization and weed control beyond current practice to accelerate growth and address potential impacts relative to current BMPs that were not developed for SRWCs.

Sustainability/Economic Assessment: A complete assessment is not within the scope of our project. We plan to do an economic assessment for supplying pine feedstocks at the end of the rotation using local costs and values. Our project team is writing a review manuscript on environmental considerations for SRWC production.

Model Validation: Though, substantial groundwater fluxes from the basin and low stream water yields rendered standard calibration difficult, our distributed measurements of hydrologic states (i.e., groundwater levels, interflow, and soil moisture) allowed multi-objective calibration such that MIKESHE and the Oregon State University models reproduced observed processes.

ENABLING SUSTAINABLE LANDSCAPE DESIGN FOR CONTINUAL IMPROVEMENT OF OPERATING BIOENERGY SUPPLY SYSTEMS

(WBS #: 4.2.2.60)

Recipient:	Antares Group Inc.
Principal Investigator:	Kevin Comer
Project Dates:	4/1/2016–3/31/2021
Project Category:	New
Project Type:	FY 2015—Landscape Design for Sustainable Bioenergy Systems: DE-FOA-0001179
Total DOE Funding:	$9,000,000

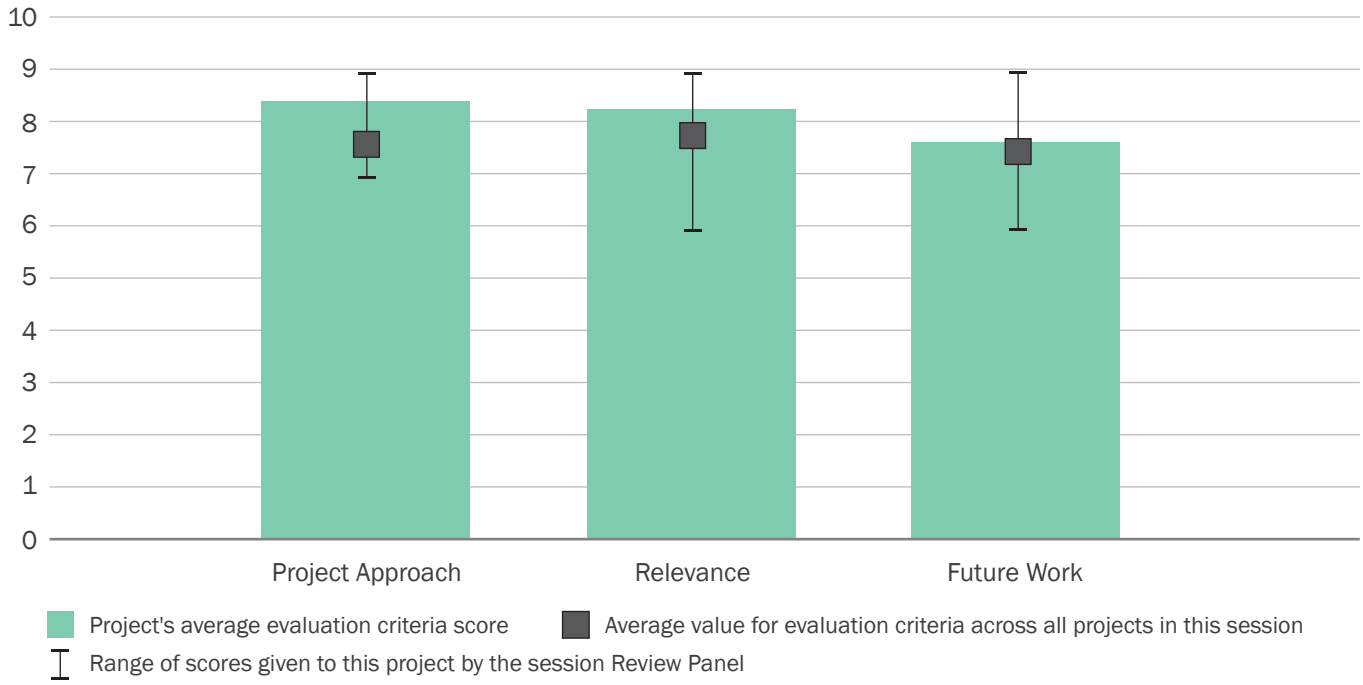
Project Description

The best and most immediately relevant opportunities to develop and demonstrate innovative and impactful landscape design practices for bioenergy systems exist within the feedstock supply sheds of operating bioenergy projects. This project will be conducted in the biomass feedstock supply sheds serving POET-DSM Advanced Biofuel's Project LIBERTY biorefinery in Emmetsburg, Iowa and DuPont Cellulosic's biorefinery in Nevada, Iowa. These are areas where LUC is already underway but is still early in its evolution in supporting the supply chains of groundbreaking cellulosic biorefineries.

The project will build from information available from these operating bioenergy systems and collect additional data necessary for addressing barriers and stakeholders' objectives. Ongoing engagements of stakeholders at key steps in the supply chain will ensure that their objectives and ideas are a part of the evolving design. When fully developed, documented, and demonstrated at these commercial scales, the landscape design activities, associated enabling tools, and best practices developed through this project will serve as important examples for sustainable bioenergy production that can be adapted and imple-

Weighted Project Score: 8.0

Weighting: Approach–25%; Relevance–25%; Future Work–50%.



mented nationwide. Our team is focused on sustainable landscape design activities and opportunities in target watershed areas including agronomic and sustainability analysis as well as tool development, field and logistics research, and demonstration work.

Overall Impressions

- This project is somewhat unique in the BETO portfolio. The project aims to work with growers and biomass end users to utilize subfield agronomic models to target areas within the existing feedstock supply to implement conservation practices and monitor key environmental indicators in hopes of better enabling the development of a sustainable biomass supply system. It does this from a bottom up approach. The project's strength comes from the involvement and close ties to growers, the biofuels industry, equipment manufacturers, and others. It is highly collaborative and integrates all stakeholders along the value chain. By involving agricultural students in the work, the project is helping to inform and shape the next generation. I also appreciate the cost share of the partners involved in the project. For being less than a year old, the project has accomplished a great deal. The team has signed up over 3,000 acres to participate in the project, done the initial watershed-level opportunity mapping, field research planning, and initial testing. Work on a web-based sustainability tool is also underway. I find it interesting that between 2 to 3 million acres of crop land are planted each year but are expected to produce a loss. Identifying and using this land for more productive purposes could save over $1B a year just in lost capital. This project strives to find better strategies for building energy crop supplies sustainably and profitably. It's compelling to think that by adopting a zonal management of the land, growers could save money, grow an energy crop, and provide environmental benefits. However, this will require, as the team points out, changing the culture of agriculture. I like how this project helps to support the State of Iowa's goals to reduce nutrient loss. It will be critical to understand what the minimum size a subfield needs to be so that a change in management practice is practical as well as profitable. Future work will include field selection and data collection, base model development to measure environmental and socioeconomic sustainability indicators, ongoing multi-stakeholder outreach activities, and annual harvesting and monitoring. It will be critical to continue to work closely with equipment manufacturers to develop the planting and harvesting equipment required for some of these new energy crops. One of the most exciting aspects of this project is that the work done in Iowa around the two existing cellulosic ethanol plants could be used to create a template that could be deployed elsewhere. Finally, asking farmers to plant perennials is seen as risky. This project helps mitigate that risk and gives farmers a chance to experience biomass crops so that when the time comes they will be informed and ready. Overall, this is a huge effort, but it has the potential to be very important.
- The project represents a massive and, in my opinion, important undertaking. The project team appears to have established a robust management approach and has already engaged a wide variety of external stakeholders from multiple sectors. I do not have any additional comments or suggestions at this time.
- This is a very ambitious, and expensive project (though with respect to the latter, costs are being shared). Its success hinges on the ability specifically to target areas that would be more profitable growing energy crops than conventional ones. Moreover, its results will only be useful if they can be generalized. It would not be cost-effective to spend this much in analysis for every parcel of a vast landscape, so it is important to determine if phenomena such as the inverse correlation between economic

profitability and nitrogen loss is general. Similarly, we would want to know if such areas are also capable of profitably growing energy crops.

- This is a great project with unparalleled data collection efforts.
- This is an ambitious, important, and complex project--logistically and technically—in terms of validating how state-of-the-art tools and best practices for targeting biomass production can provide economic as well as environmental benefits. The idea of the project is excellent and the stakeholder engagement appears a major strength. The continual improvement aspect also seems innovative. It would be great to be more explicit about how and what information collected would be used for adaptive management over time. It will be critical to ensure well-defined milestones and management practices to maximize the value of this major flagship project.

  In particular, on the environmental side, it is not clear what and how environmental indicators are going to be measured and monitored on the field and what was going to be modeled. This will be a critical component to demonstrate environmental and economic performance. It will be important to ensure this project is drawing on some of the best technical practices developed in other projects, for example, the work on evaluating conservation practices to reduce nutrient loss under #4.2.1.10 led by Dr. Negri, on subfield targeting with the Landscape Environmental Assessment Framework (LEAF) model under #4.2.1.20 led by Dr. Nair, and spatially detailed modeling by the University of Minnesota (#1.7.17).

PI Response to Reviewer Comments

- Our project has a very detailed project management plan that is reviewed quarterly with our DOE project managers and our internal project management team. Our team meets monthly with our DOE project management team to review progress, challenges, plans, proposed adjustments, and issues associated with our management plan. The project has 40 specific milestones and 31 deliverables that are part of our management plan, and our progress is tracked against those metrics on an ongoing basis. There is an annual go/no-go decision milestone associated with our demonstrated progress (at DOE's discretion), and there will be a stage-gate review involving a panel of independent expert peer reviewers about 2 years into our project performance period. We have already exceeded the requirements of several of our peer review metrics. The requirements for accomplishments by our team by the time of the stage-gate review are as follows: (1) accomplished considerable interaction and planning with state and local stakeholders; (2) evaluated and selected target fields and practices for implementation; (3) performed subfield analysis and planning for each field; (4) collected results from initial field baseline monitoring; (5) performed initial harvest demonstrations and related performance monitoring, analysis, and reporting; (6) developed an initial web-based interface for collecting sustainability related information for use in a sustainability certification process; and (7) developed and demonstrated a range of modeling capabilities to assist with the previously mentioned activities and regional modeling of impacts from larger-scale implementation of the conservation and biomass establishment practices considered in the project.

  Our project team, with the help and encouragement of our DOE project management team, regularly interacts with the researchers mentioned above and others who are engaged in important work that is relevant to this project. In some cases, such as Dr. Jager's work, our project will serve as a field testing platform and collaborator for a researcher's analytical work—we offer them a field testing environment and case study opportunity, and they provide our

team with the results of their analytical work. In other cases, such as the work described in Dr. Nair's presentation on the LEAF model, those researchers are part of our team and those models are directly incorporated into our modelling methodology. The LEAF model is incorporated into AgSolver's existing set of services and commercially available tools. AgSolver is a vehicle for getting those tools, and new improvements, into commercial application as quickly as possible once those tools and improvements have demonstrated commercial value and readiness. We are open to and interested in collaborating with any researcher or organization that has interest in our project activities, objectives, information, and capabilities or stakeholders that we can leverage to further our team's objectives.

This project's field monitoring results will be used to validate and/or calibrate the software tools our team members are developing, improving, and using. One of the most important outcomes from developing and improving these computer models is building the capability to accurately transfer field research results and measurements (from this and other projects) to broader and different circumstances, without having to incur the same level of field-related effort and expense. Our project is already benefiting from decades of plot-scale field research and geophysical model development. We will build upon that work and demonstrate the usefulness of the resulting modelling tools to assist with improved decision making for farm managers, government program managers, and policymakers.

BIOFUELS INFORMATION CENTER (BIC)

(WBS #: 6.3.0.1)

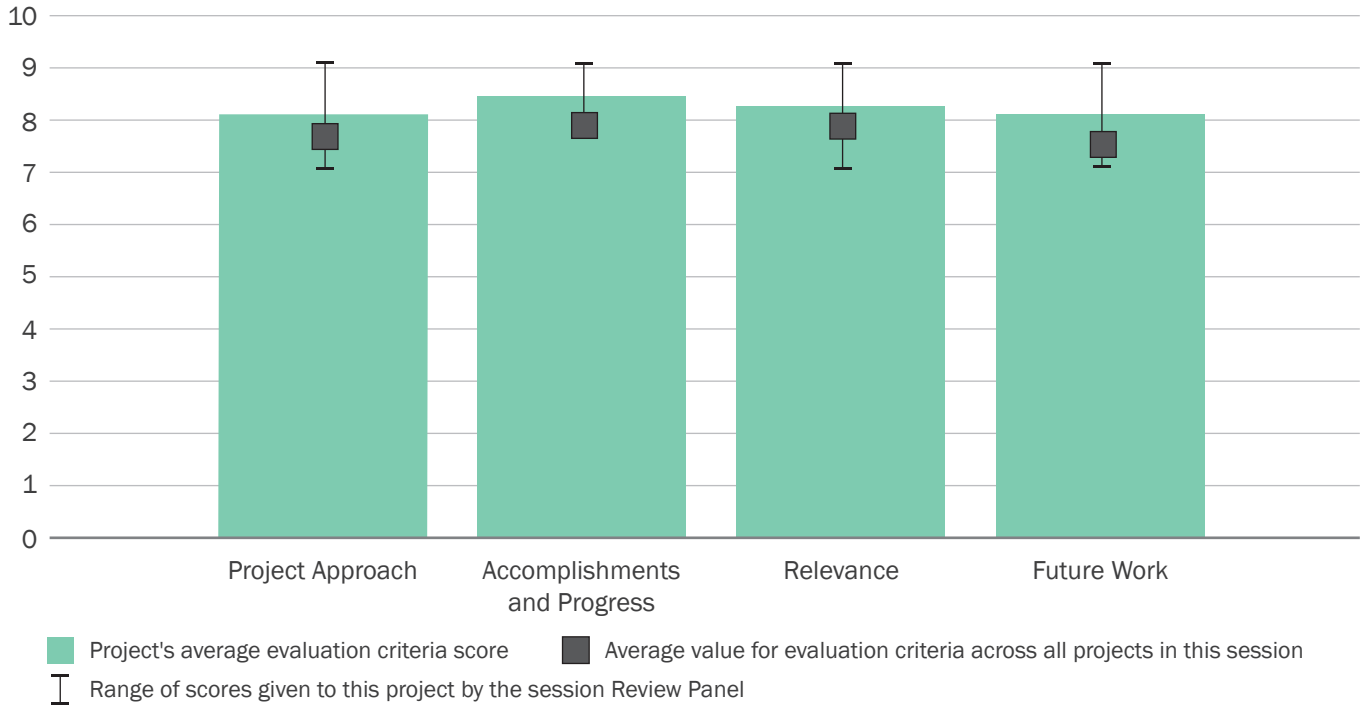
Project Description

Recipient:	National Renewable Energy Laboratory
Principal Investigator:	Kristi Moriarty
Project Dates:	10/1/2013–9/30/2017
Project Category:	Ongoing
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$200,000
DOE Funding FY 2015:	$120,000
DOE Funding FY 2016:	$110,000
DOE Funding FY 2017:	$500,000

The purpose of BIC is to provide relevant data, information, reports, and web-based tools to all bioenergy stakeholders. This BIC task supports biofuels pages on EERE's website—the Alternative Fuels Data Center (AFDC; afdc.energy.gov) and the Bioenergy Atlas tools (maps.nrel.gov).The BIC task began in FY 2008 to meet the requirement under Title II, Sec. 229 of the *Energy Independence and Security Act of 2007* which requires DOE to develop a biofuels and biorefinery information center. The task also supports the PI's time to engage stakeholders on infrastructure and biofuels. This includes leading and participating in committees on biofuels and infrastructure as well as engaging with specific companies needing data and information in this area. In FY 2017, this task grew to include analysis of a USDA's Biofuels Infrastructure Partnership and the annual *EERE Bioenergy Market Report*. This task results in nearly 800,000 web page views per year on an average budget of $150,000/year. A key challenge is purchased data set restrictions which are mitigated by working with the vendor to show a range rather than exact data. The outcome and technical accomplishments are heavily used AFDC biofuels pages and Bioenergy Atlas tools as well as two annual reports beginning in FY 2017.

Weighted Project Score: 8.2

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



Overall Impressions

- BIC provides essential bioenergy data, tools, and information to all stakeholders. The goal of this project is to enable stakeholders to make informed decisions by providing the information they need. While a small team, the project is well managed with clearly defined goals. It is great that USDA serves as a full partner in this work. Collaboration across the various functions is key. BIC focuses on providing useful bioenergy tools, data, and information. The work includes updating and maintaining AFDC; updating, maintaining, and adding functionality to the Biofuels Atlas and Biopower Atlas geospatial tools; and leading and participating in stakeholder committees and groups on the subject of biofuels infrastructure compatibility. The outreach component of this work is critical. The team uses a variety of methods to highlight its work including webinars which can be an effective method to reach the stakeholder community. BIC is important and helps BETO meet its goal of expanding the domestic bioenergy market by providing current, relevant bioenergy data and tools to a wide group of stakeholders. These stakeholders are often not the scientific community but are fueling station owners, vehicle manufacturers, biofuel producers, local governments, and consumers. Engaging stakeholders helps to debunk myths, create an informed understanding of the issues, and overcome the obstacles necessary to get new fuels into the marketplace. An example BIC's impact is the number of page hits the site receives. In 2016, BIC had over 740,000 page views. Future work will include continued support of AFDC and Biofuels Atlas tools, continued engagement of stakeholders, and completion of the *Bioenergy Market Report*. Because of its deep expertise in dealing with infrastructure issues, it would be great if this team could work with the Co-Optima Market Transformation team to evaluate the necessary infrastructure changes that will be required with some of the novel, new blendstocks.
- In many ways, BIC is hard to evaluate given the legislative or programmatic mandate for many of its activities. Still, the project seemed to have a large reach for a relatively modest budget. The project team demonstrated commitment to stakeholder assistance, potentially multiplying the impact of the program beyond its formal products and deliverables.
- This is a project that involves the collection and dissemination, rather than the production, of data. As such it is more difficult for someone like me, whose expertise lies more in primary research, to assess its merits. I am impressed, however, that usage seems to be high. It will be important to follow usage statistics in the years ahead to see if additional investments might further expand the user base, or if it has plateaued. Of course, it may still be useful to make investments in broadening BIC offerings.
- This seems like one of the most widely used bioenergy data- and tool-dissemination vehicles. As such, it is a critical challenge to stay current and maximize value to users. The project is doing an impressive job of generating downloads but could incorporate even more outreach to users as well through webinars and other efforts to promote broader knowledge and usage of Atlas and other tools.

  It would be valuable to present more information on how this website fills a gap relative to what is being provided by private industry and others and on the usage compared to other pages at DOE and other organizations.

  It is also critical to cross-fertilize investments in this, Bioenergy KDF, and other dissemination platforms to ensure cost-effectiveness and maximize exposure and usage.
- The website is attractive and functional. The data are easy to find and navigate and the system's responses are quick.

The ability to download data layers is an important addition to the functionality. The team has incorporated many data layers. The Biofuels Atlas and Biopower Atlas websites work well, data are downloadable, and queries are flexible and quick. The team has just published the 2015 *Bioenergy Market Report*, useful information for informing industry and policy-influencing stakeholders. This is an important contribution to bioenergy literature.

The key missing piece seems to be recognition of the relationship to other efforts. In particular, the relationship between the BIC and the Bioenergy KDF is not clear. Why should these projects not be handled under a single "umbrella?" BIC appears well managed and capable of incorporating the roles of the Bioenergy KDF under a single project management structure including NREL and ORNL contributors. This would promote efficiency in the use of budget.

PI Response to Reviewer Comments

I appreciate the reviewers' time in providing thoughtful input and comments. BIC supports the biofuels pages on the AFDC, an EERE website available for more than 20 years. The Biofuels Atlas and Biopower Atlas tools were purposefully designed in Google Maps for ease of use by a variety of stakeholders. The tools provide a multitude of bioenergy and related datasets on one webpage. Usage of the Bioenergy Atlas tools grew by 44% between FY 2015 and FY 2016 as a result of a redesign and outreach. The BIC and Bioenergy KDF tasks both complement and differ from one another. The emphasis of the BIC task is on existing feedstocks and infrastructure data while the focus of the Bioenergy KDF is on forward projections of feedstocks. NREL, with stakeholder input, selects, updates, and maintains data and information available in AFDC, Biofuels Atlas, and Biopower Atlas. The Bioenergy KDF allows users to upload and share bioenergy publications and data with a mapping application focused on showcasing data from the BT report series. Automated methods allow sharing of data between tools.

BIOENERGY KNOWLEDGE DISCOVERY FRAMEWORK

(WBS #: 6.3.0.2)

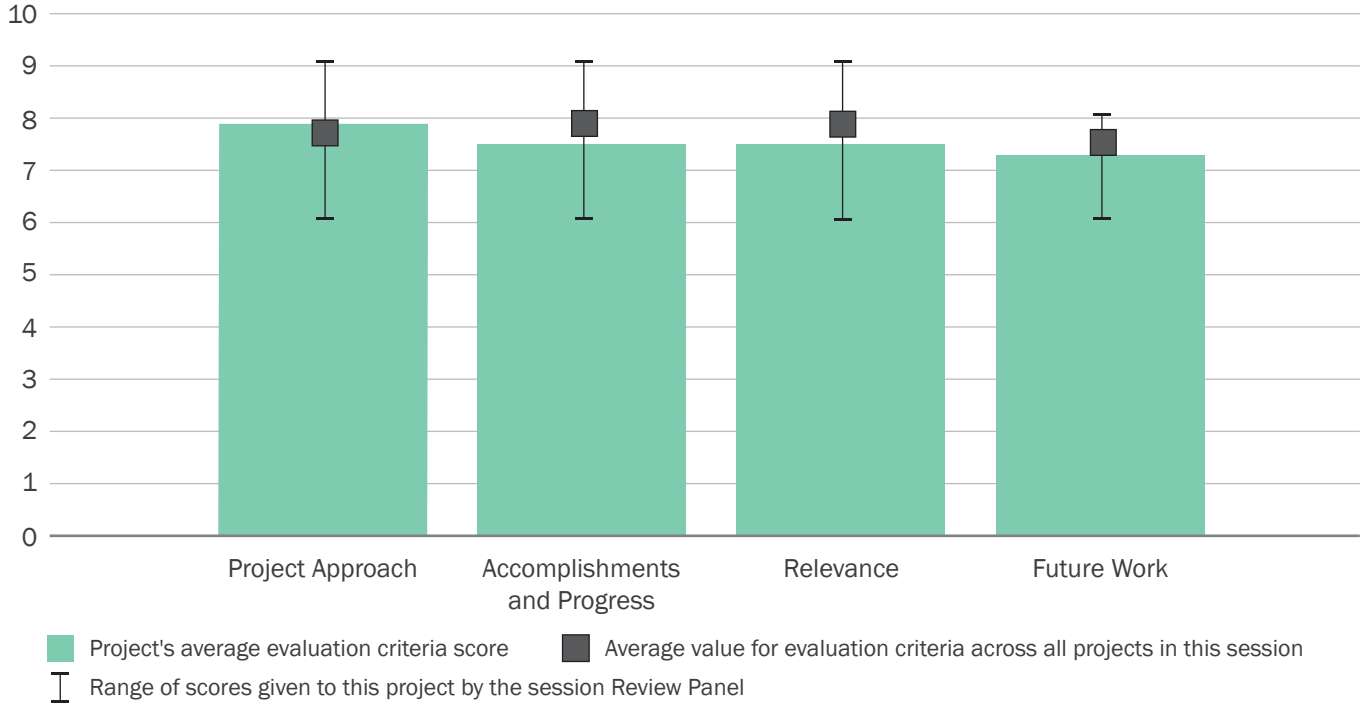
Project Description

There are many issues in the biofuel supply chain ranging from production to delivery that have to be addressed in order to foster a viable biofuel industry. Infrastructure issues related to generation, distribution, and delivery of biofuels include finding the optimal locations to site biorefinery to minimize cost with adequate availability of feedstock resources nearby. The Bioenergy KDF is a collaborative platform for knowledge creation, collection, curation, and discovery to support DOEs effort to develop a sustainable biofuel industry. The Bioenergy KDF facilitates informed decision making by providing a means to synthesize, analyze, and visualize vast amounts of information in a spatially integrated manner. The Bioenergy KDF enables data harmonization from different sources, serves as a source of authoritative and benchmark datasets, and provides integrated decision-making capabilities to its stakeholders. It serves as an open platform, leverages collaborative aspect of the internet to catalogue and share datasets and other relevant information. The Bioenergy KDF will also host "apps" addressing different bioenergy related problems. These apps will include techno-economic models, routing models for transportation, and apps for visualizing different feedstock production scenarios.

Recipient:	Oak Ridge National Laboratory
Principal Investigator:	Aaron Myers
Project Dates:	10/1/2007–9/30/2020
Project Category:	Ongoing
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$400,000
DOE Funding FY 2015:	$400,000
DOE Funding FY 2016:	$250,000
DOE Funding FY 2017:	$300,000

Weighted Project Score: 7.5

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



Overall Impressions

- The Bioenergy KDF is designed to be a one-stop shop repository for data and information generated by BETO. It serves to connect researchers, industry, and sponsors and to share information within the bioenergy research community. One of its strengths has been its ability to make high-value data and information easily accessible through an interactive web-based architecture. There is no better example than the work that went into making *BT16* easily accessible. Collaboration and community engagement are the key to success with this project. Progress since the last review included updating the Bioenergy KDF architecture, enabling access to the high-octane fuel study, and releasing *BT16*. The tool appears to work well and considerable effort is made to make the data and the reports as accessible and interactive as possible. It should not come as a surprise that one of the greatest challenges is getting people to use the system. Perhaps if there was some way to incentivize people to use the system as part of their project goals or funding it would be easier to get people to use it. The Bioenergy KDF serves as a single point of contact and the place to go to get things like *BT16*. This can be seen by the spike in users when a major report like *BT16* is released. The Bioenergy KDF serves to enable collaboration across the various programs by providing researchers with access to the tools, data, and information needed to help further research. It also serves to provide a mechanism for the dissemination of a consistent, science-based message. In addition to the scheduled software updates and enhancements, I would encourage continued integration with other data repositories. I also applaud the efforts to update and enhance a legislative library, as this serves an important link between BETO and legislators. I would also recommend increasing the visibility and use of the site.
- The Bioenergy KDF appears to be a necessary component to the larger BETO mission that is often overlooked. Efforts have obviously been deployed to cleaning up the portal and expanding capabilities. Future efforts must be devoted to fostering a viable user community if this effort is to achieve its potential.
- We were asked to review several types of projects, and the standards we employ in evaluating ones like this, where the objective is to organize and present information, will differ from those we use in others, in which the objective is to generate information. I do not have particular expertise in this area, and have not been a user of such data. Perhaps the most useful thing I can say is that it is important to continue to use analytical methods to identify events that trigger site usage and develop plans for improvements.
- This appears to be a top-notch dissemination platform. Dissemination of work and tools across all the projects is centrally important to all BETO efforts. It is a high priority for BETO to freely share and promote data sharing as this engages stakeholders and enhances the credibility of all its work.

  The main question is how valuable the specific tools and information provided by the Bioenergy KDF are to users. To understand the benefits and how best to maximize them, an identification of the target audience and assessment of user reviews and needs is a priority and should be central to project planning going forward. For example, perhaps users would prioritize certain decision-support capabilities or prefer the ability to obtain more underlying data to run analyses with their own assumptions.

  To understand costs, an assessment of the longer-term maintenance needs and potential options to ensure sustainability would be valuable, including options to scale up the site to be a broader platform across, and potentially beyond, BETO. To the extent

possible, technical administration and design of different dissemination platforms across project should also be integrated to reduce any duplicative costs.

- The Bioenergy KDF is a useful repository of research from BETO. However, it is limited in its coverage and usefulness to stakeholders. Moving forward, the project should work with stakeholders to more clearly establish how the project adds value and then focus efforts on key contributions the Bioenergy KDF can make that would not happen otherwise.

If this project goes forward, it is important to distinguish the Bioenergy KDF from other data repositories. If the distinguishing factors are visualization capabilities that are costly to create and maintain, it is worth considering whether they are worth pursuing and to answer that question based on expressed stakeholder needs.

To justify the project moving forward, it is important to better track what users are visiting the site for and to determine what features and data are most useful.

PI Response to Reviewer Comments

- Thank you for your feedback.

CEMAC: MARKET ANALYSIS OF BIOMASS-BASED CHEMICALS SUBSTITUTIONS—NREL

(WBS #: 6.3.0.5, 6.3.0.6 and 6.3.0.7)

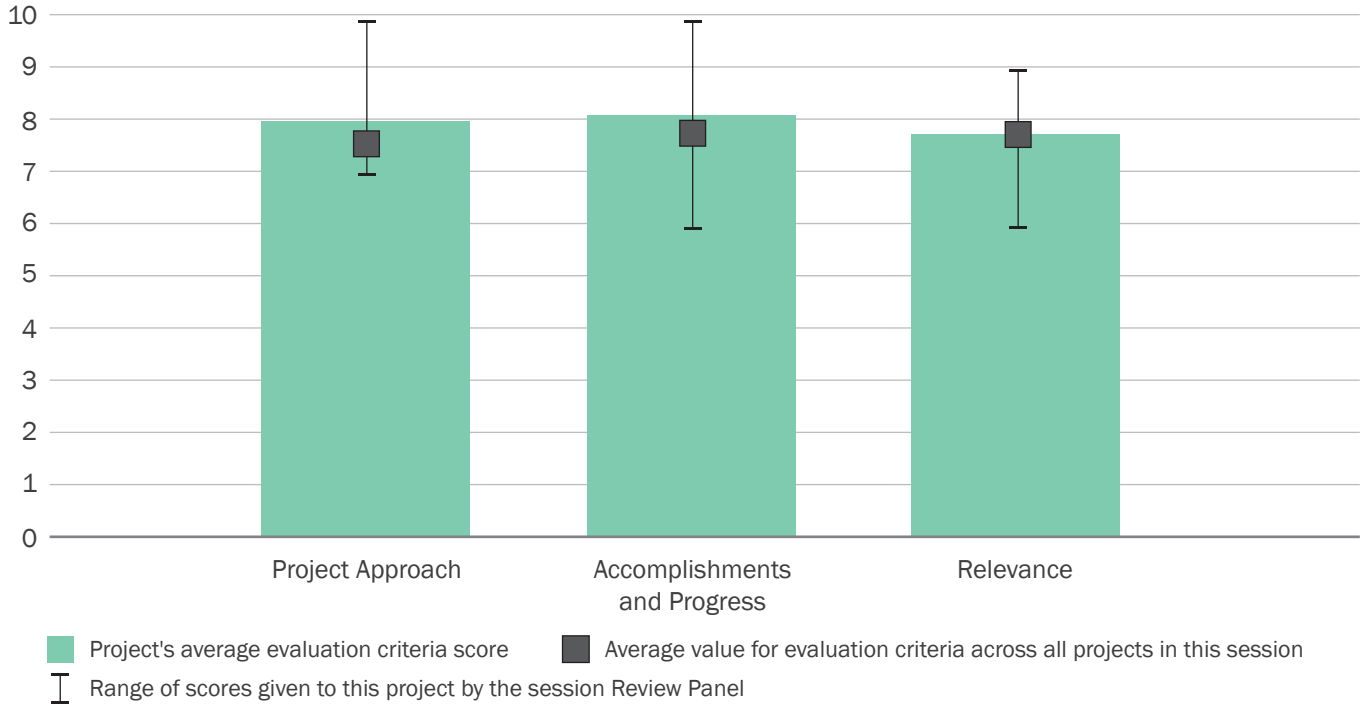
Project Description

CEMAC performs high-impact analysis, benchmarking, and assessment of supply chains and manufacturing for clean energy technologies that can be applied by decision makers to inform R&D, policy, and investment directions. Established in 2015, CEMAC is housed at NREL and operated by the Joint Institute for Strategic Energy Analysis. CEMAC engages DOE, U.S. federal agencies, national laboratories, universities, and industry to promote economic growth and competitiveness. This collaborative project, which includes ANL, NREL, and PNNL, is conducting a global supply chain and market analysis for chemicals synthesized from lignocellulosic biomass. The project goal is to elucidate the manufacturing costs and value-added along the supply chain, U.S.-specific competitive advantages, and the potential market impact of biomass-derived chemicals.

Recipient:	Argonne National Laboratory, National Renewable Energy Laboratory, Pacific Northwest National Laboratory
Principal Investigator:	Maggie Mann
Project Dates:	10/1/2015–3/31/2017
Project Category:	Sun-setting
Project Type:	Annual Operating Plan
DOE Funding FY 2014:	$0
DOE Funding FY 2015:	$550,000
DOE Funding FY 2016:	$425,000
DOE Funding FY 2017:	$0

Weighted Project Score: 8.1

Weighting: Approach 25%, Relevance 25%, Accomplishments and Progress 50%



Overall Impressions

- The goal of this project was to develop analyses and methodologies to understand the manufacturing costs and potential market impacts of lignocellulosic-derived chemicals with the intent that these results be leveraged by decision makers to inform investment strategies, policy, and other decisions necessary to promote economic growth and competitiveness in a bioeconomy. The project was well managed with a strong team of collaborative partners from academia, the national laboratories, and industry. Monthly calls and clear deliverables helped to keep the project focused and productive. In an effort to evaluate the production of chemicals from biomass, the team evaluated over 170 bioproducts using a range of metrics including economics, markets, and sustainability drivers. These bioproducts were down-selected using the set of screening metrics the team developed. From these, three case studies were performed to evaluate economics, U.S. and global markets, and supply chain needs. The findings were outlined in a detailed report of the study. Preliminary results showed that 20 of the products could offer significant benefits. Consistent with my own findings, the team identified scale-up risk and accessible supply chains as important criteria when considering bioproducts. This project aligns well with BETO's goals to develop a deeper understanding of bioproduct markets, economics, and sustainability. The study went beyond just techno-economic considerations to include market drivers and sustainability metrics in evaluation. This work is very important and should be continued as a part of other BETO projects. Biobased chemicals and bioproducts could serve as enablers for the biofuels industry. Already, as the study found, there are examples of bioproducts being produced at a commercial scale. These products could help mature the biomass supply chain and provide initial wins for the bioeconomy. While this is a sun setting project, many questions remain. I would recommend including this work in other BETO projects as appropriate.
- The project seems to have achieved its objectives. Outputs were reasonable. Integration with other efforts appeared to be reasonable and well thought out.
- My two main concerns with this project are as follows: (1) Because it was difficult to find many chemicals that might be treated as case studies, it is hard to know how representative and transferrable the results of the exercise are. (2) Without knowing more about the nature of the processes and products of the petrochemical industry, it is hard to know how the growth of alternative, biologically derived chemicals might impact the production and sales of environmentally harmful petrochemicals.

  I should hasten to add that the second concern likely arises as much from the limitations of this reviewer than from any fault of this project. Both concerns may point to opportunities, however, to expand the scope of the analysis, as well as of reports of its results.
- This seems like a potentially seminal project for understanding the U.S. bioproducts opportunity. The project has focused on the technical analysis but would benefit from stepping back and looking at the big picture in terms of the potential economic and environmental benefits. Key questions are: What and how large are these potential benefits and what are the trade-offs with other uses and approaches to achieve them? This would help identify the potential value of next steps. The publication of the final report is important, including finding ways to disseminate through the Bioenergy KDF, BIC or other platforms.
- This is a strong, well-managed project. It is also important that the data produced for this project are released in a manner suitable for incorporation in future studies. The research questions were clearly

defined and the approach is adequate and appropriate. It would be helpful to more clearly define the metrics by which the successes of the project are measured.

The project produced a large amount of results/information. It is important that these results are documented in peer-reviewed reports and articles. Could the project team comment on how this will be done following project sunset?

PI Response to Reviewer Comments

No official response was provided at the time of report publication.