DEMONSTRATION AND MARKET TRANSFORMATION

TECHNOLOGY AREA

CONTENTS

INTRODUCTION

During the Demonstration and Market Transformation (DMT) session, six external experts from industry, academia, and other government agencies reviewed a total of four projects.

This review focused on DMT's integrated biorefinery (IBR) portfolio and addressed a total U.S. Department of Energy (DOE) investment value of approximately $93.7 million, which represents approximately 13.3 % of the Bioenergy Technologies Office (BETO or the Office) portfolio reviewed during the 2017 Project Peer Review. The Co-Optimization of Fuels and Engines (Co-Optima) consortium project, which is part of the DMT portfolio, was reviewed in a separate session due to the complexity and scale of the work. The Co-Optima review addressed a total DOE investment value of approximately $50 million, with BETO contributing $26 million and the Vehicle Technologies Office contributing $24.5 million (fiscal year [FY] 2015–2016 spending).

During the Project Peer Review meeting, the principal investigator (PI) for each project had 30 minutes to provide an overview of their project and its status 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. This section also includes overview information on the DMT Program, full scoring results and analysis, the Review Panel's summary report, and BETO's programmatic response.

BETO designated Borka Kostova as the DMT Technology Area Review Lead. In this capacity, Dr. Kostova was responsible for all aspects of review planning and implementation.

DMT OVERVIEW

DMT's goal is (1) to de-risk bioenergy production technologies through validated proof of performance at the pilot, demonstration, and pioneer scales and (2) to conduct activities that will transform the bioenergy market by reducing or removing commercialization barriers. This is achieved through public-private partnerships that build and operate IBRs and through projects focused on addressing technology, biofuels and bioproducts distribution infrastructure, and end-use market barriers and opportunities. DMT helps to address the links of the bioenergy supply chain and works to enable a robust demand for end products

The DMT Program manages a diverse portfolio of IBR projects, which is focused on the scale-up of biofuels production.

In FY 2015, DMT managed a portfolio of 28 projects, including 2 at pioneer scale (plus 3 pioneer-scale projects co-managed within Defense Production Act), 7 at demonstration scale, 12 at pilot scale, and 4 additional projects selected under at the Innovative Pilot funding opportunity announcement (FOA) to support aviation and military fuel applications. The conversion pathways addressed included 13 biochemical technologies, 7 thermochemical technologies, and 5 algal technologies. The active portfolio included 13 projects focused on cellulosic ethanol, 12 projects focused on renewable hydrocarbons, and 1 project focused on renewable intermediate biochemical products.

The majority of these projects were funded by the American Recovery and Reinvestment Act of 2009 and were completed by the end of FY 2015.

In FY 2016, 8 projects from the prior portfolio of 28 projects were still ongoing: two at the pioneer scale producing cellulosic ethanol, three co-managed within the Defense Production Act producing renewable diesel and jet fuel, and three at a small pilot scale producing renewable hydrocarbons, such as military-specification diesel and aviation fuel.

Another important element of the DMT portfolio is the Co-Optima consortium project. The Co-Optima initiative is a collaborative effort between the Vehicle Technologies Office, BETO, nine national laboratories, 13 universities, and numerous industry and government stakeholders. Co-Optima's coordinated engine and fuels research and analysis are providing the framework for the co-development of fuel and engine technologies that, when used in tandem, offer the greatest combination of efficiency and performance. BETO explicitly seeks to identify biomass-based blendstock options since they have the potential to increase domestic fuel sources and provide additional environmental, social, and economic benefits. The Co-Optima portfolio was reviewed in a separate session due to the scale and complexity of the work.

DMT Support of Office Strategic Goals

The DMT Technology Area's strategic goal is to contribute to (1) developing commercially viable bioenergy technologies through public-private partnerships that build and validate pilot-, demonstration-, and pioneer-scale IBRs and (2) developing supporting infrastructure to enable a fully operational and sustainable biomass-to-bioenergy value chain in the United States.

DMT focuses on reducing risk to the consumer and the private sector and on helping overcome challenges to financing the follow-on expansion of the industry, which is required to make a major contribution to our nation's energy independence and security. In addition, DMT facilitates developing novel methods for expanding the end-use market for biofuel and bioproducts.

DMT Support of Office Performance Goals

A specific DMT goal in support of BETO's performance goals is as follows:

By 2017, validate a mature technology modeled cost of cellulosic ethanol production, based on actual IBR performance data, and compare to the target of $2.65/gallon ethanol ($2014).

DMT Approach for Overcoming Challenges

Current DMT activities generally fall into five categories: analysis and sustainability, technology interface, feedstocks, IBRs, and infrastructure and end use. DMT activities are performed primarily by industry partners, with national laboratories and universities also making significant contributions.

Below, BETO has identified the market and technical challenges and barriers for which improvements are crucial to reaching DMT program goals.

Market Challenges and Barriers
• Inadequate feedstock supply chain infrastructure
• High risk of large capital investments
• Codes, standards, and approval for use
• Cost of production
• Offtake agreements
• Uncertain pace of biofuel availability
• Biofuels distribution infrastructure
• Lack of acceptance and awareness of biofuels as a viable alternative

Technical Challenges and Barriers
• End-to-end process integration
• Risk of first-of-a-kind technology
• Technical risk of scaling
• Engines not optimized for biofuel

Analysis and Sustainability

Both project-specific and portfolio-wide evaluations assess progress toward objectives and sharpen the focus of DMT strategies on the areas with the highest potential impact to the industry. These evaluations, which encompass a broad range of technical performance and economic, social, and environmental sustainability metrics, are updated annually to reflect developments within each project and the industry. Specific metrics include process performance by unit operation; financial data, including pro forma and actual capital and operating costs; and sustainability metrics, including water usage, life-cycle greenhouse gas emissions, and jobs created. These data are used to monitor progress against goals, assess the current state of technology for various biomass-utilization technologies, and determine the projected commercial impact of various projects.

Technology Interface

DMT projects integrate broad sets of technologies from Feedstock Supply and Logistics and Conversion Research and Development (R&D). Technology interface activities help identify (1) technologies that are ready for piloting and scale-up, (2) entirely new feedstock logistics systems or conversion technologies, or (3) improvements to a smaller set of unit operations. In addition, new challenges discovered during scale-up are shared in a feedback loop with R&D areas to facilitate continuous learning and proactively address improvement opportunities.

Feedstocks

Biomass feedstock is an essential primary input to every IBR, and efforts to improve supply and logistics systems are essential for commercial operations. These activities span both terrestrial feedstock and algal feedstock systems to identify areas for improvement in feedstock supply and logistics systems and in the development of advanced feedstock logistics systems.

Integrated Biorefineries

Validating performance at integrated pilot, demonstration, and pioneer scales is essential to de-risk technology and enable financing that will catalyze the transition to large-scale renewable fuel and bioproducts production. Operations at each of these scales systematically address many of the market and technical barriers previously identified. Integrated pilots prove the end-to-end process and develop engineering modeling tools. Demonstration-scale facilities then allow for more optimized equipment specifications and can manufacture products for commercial acceptance, which can lead to offtake agreements for the pioneer plant. Finally, pioneer plants prove continuous economic operation with large-scale supply chains. Operational data at each scale are also used to address many other barriers, including sustainability.

The success of IBR projects is expected to help to de-risk the technology to facilitate future commercial financing for biofuels, bioproducts, and biopower production. Analogous to the petrochemical industry's development of refinery infrastructure, biorefinery projects showing success should translate into better financing potential.

Infrastructure and End Use

In addition to the significant risks involved with scaling up new biorefinery technology, other market barriers

related to infrastructure and end use also limit advanced biofuel production. Efforts in this area focus on enabling higher rates of renewable fuel usage in current markets while addressing barriers for expansion into new markets, such as home heating oil. Specific efforts in this area are to establish linkages early in the R&D cycle of both fuels and engines. Co-development of fuels and engines could result in expanded markets for renewable fuels, improvements in vehicle engine efficiency, and reductions in life-cycle greenhouse gas emissions.

BETO works closely with DOE's Vehicles Technology Office (1) to identify the opportunities and challenges associated with the development of new fuel specifications and (2) to assist stakeholders in developing and deploying optimized vehicle systems, new fuel compositions, and compatible infrastructure needed to achieve increased advanced biofuels use in the U.S. transportation system. Specific activities are focused on identifying critical fuel properties needed to optimize performance of advanced spark-ignition and compression-ignition engines, identifying biomass-derived molecules and mixtures with properties that maximize performance of advanced engines, evaluating pathways to production, and modeling the fuel blending behavior.

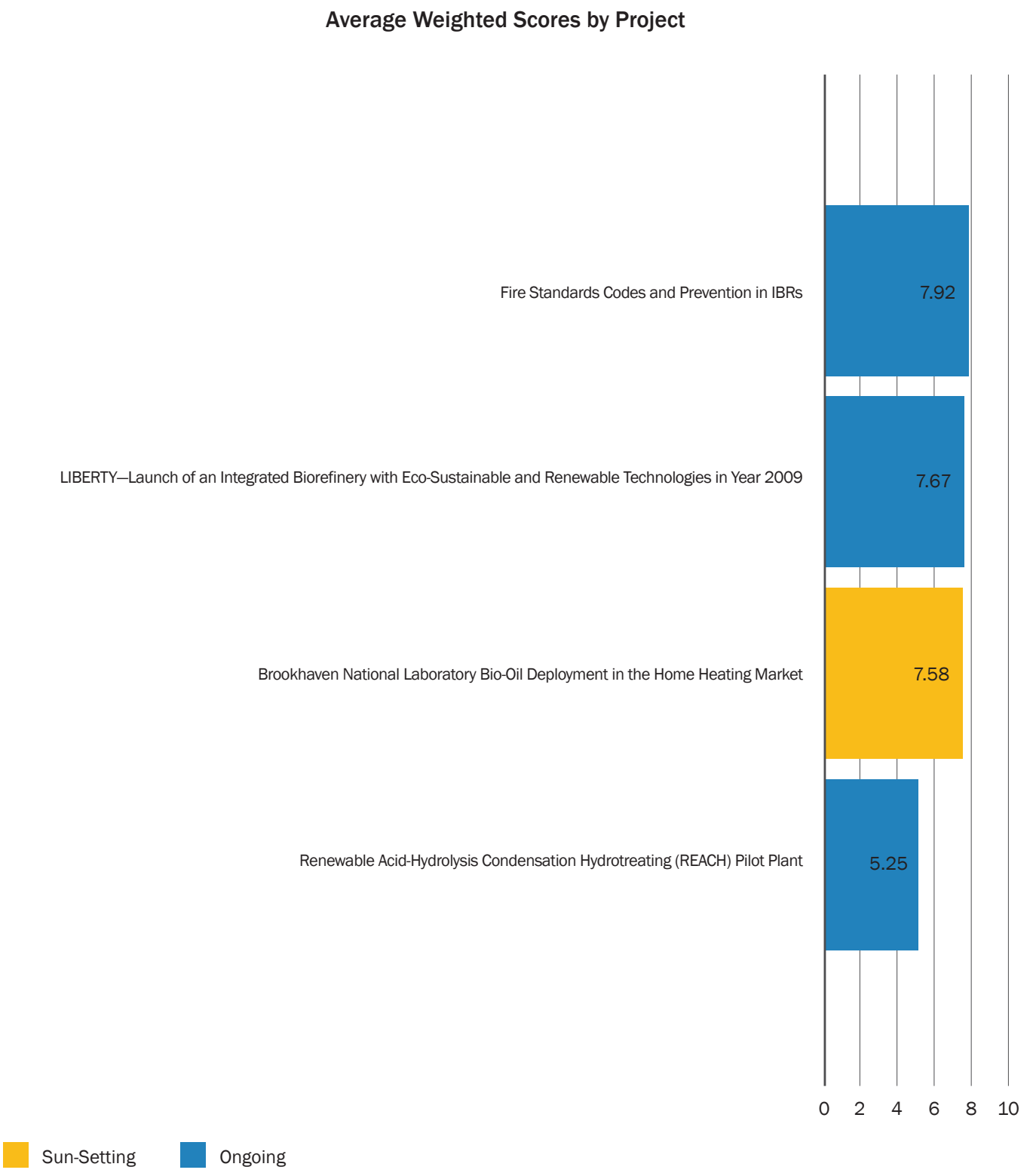
DMT REVIEW PANEL

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

Name	Affiliation
Mike McCurdy*	ICF International, previously Leidos
Alan Propp	Propp and Associates
Kerri Neary	DOE Loan Programs Office
Mark Penshorn	RES Kaidi
Danielle Sexton	Harris Group
Andrea Slayton	Northrop Grumman

* Lead Reviewer

TECHNOLOGY AREA SCORE RESULTS



DMT REVIEW PANEL SUMMARY REPORT

Prepared by the DMT Review Panel

Overview

The DMT team provides the final critical link between publicly supported R&D and private-sector commercialization of new and innovative technologies. Key barriers to the adoption of the technologies remain, including conversion costs, feedstock, and distribution infrastructure; industry human capacity building; achievement of stable/mature operations; and financing of pioneer facilities. In addition to the projects presented within the DMT Peer Review session, the DMT portfolio includes a comprehensive project named Co-Optima, which aims to develop future fuels and engines together. Due to the complexity of Co-Optima, it was presented in a separate Peer Review session.

On behalf of the Review Panel, we would like to thank both the DOE DMT team for the invitation to review the presentations and the presenters who took the time out of their busy schedules to summarize their projects to the public at large.

Impact

The DMT team has had a substantial impact on the development of the bioenergy industry by (1) investing in pioneer commercial facilities where uncertainty in the time and cost required to achieve mature operations has limited the private funding options, (2) supporting the testing of new processes at the pilot scale so that the technical feasibility and economics at the commercial scale can be established, and (3) addressing cross-technology issues with material handling, fire threats, and other issues that introduce uncertainty and risk throughout the space.

The POET-DSM Project LIBERTY pioneer plant is a perfect example of the impact of the DMT Program. Project LIBERTY represents the final step to commercialization of the technology, where stable sustained operations are demonstrated for both future plant owners and their lenders. Without an operating commercial analog to reference, lenders have been hesitant to provide financing without public-backed credit subsidies, such as loan guarantees and grants, to cover technology risks. As an operating facility, Project LIBERTY will provide the data necessary to assess the technology risks and allow owners and lenders to price loans based on conventional market risk rather than technology issues. We cannot understate the importance of this milestone. A commercially proven cellulosic biofuel design would allow the United States to unlock billions of gallons of domestic energy, revitalize rural economies, and create thousands of good-paying jobs in some of our country's most disadvantaged areas.

DMT's impact in pilot-scale testing has been limited over the past year; Mercurius Biofuels' project is the only active pilot-scale work in DMT. The Review Panel would like to encourage BETO to support more technologies at the pilot scale, as the pace of technology development is at its peak, and the pilot scale can be a particularly challenging stage for companies seeking financing. That being said, the Review Panel acknowledges and fully supports BETO's requirements for projects to make measurable progress in a timely manner and to provide the private-side cost-share funds promised at the time of award. These requirements are important to ensure a timely return on BETO's investments and to confirm that technologies have private-side support for eventual commercialization.

The Oak Ridge National Laboratory (ORNL) Fire Standards Codes and Prevention in IBRs project fits well into the third category of cross-sector issues that may have a limited impact on any one project but have a significant impact on the bioenergy sector as a whole. Fires have been a pervasive problem for the industry to date, and many of the Peer Review Panel members have witnessed or experienced fires at their projects. This project has the potential to significantly advance the state of technology for fire protection; there is currently very limited information on the subject, and each separate project has had to figure out proper fire protection methods using a trial-and-error process. By summariz-

ing this information so that it may be used by farmers and engineers early in the project, projects can eliminate costly mistakes during project development. Additionally, the actual fire testing will generate information for the fire protection engineers to minimize damage from fire while the plants are in commercial operation.

Innovation

The DMT Program contains innovative process types and methods to improve the availability of the technologies at scale. The Peer Review Panel thought that the DMT team was wise to maintain the technology diversity of the portfolio, so as not to over-concentrate investments in one area. The investment in Mercurius Biofuels' Renewable Acid-Hydrolysis Condensation Hydrotreating (REACH) liquid-phase conversion technology is an example of supporting a diverse set of technologies with commercial potential. The other, more subtle innovation is the manner in which POET-DSM's Project LIBERTY has been addressing unforeseen startup issues to improve the availability of the Project LIBERTY plant. It takes a significant amount of effort to address issues when dealing with hundreds of tons of biomass per hour, and the Review Panel commends POET-DSM's Project LIBERTY and the DMT team for their efforts in this area.

As mentioned before, the Review Panel would like to encourage BETO to support larger-scale testing of technologies outside enzymatic hydrolysis to drive some of the other innovative technologies development. While the Panel would have liked to see more projects in the DMT Program, we do acknowledge that the Project Definition for Pilot- and Demonstration-Scale Manufacturing of Biofuels, Bioproducts, and Biopower (PD2B3) FOA and IBR Optimization FOA may provide additional opportunities for larger-scale testing.

Synergies

In the Review Panel's opinion, projects in the space have significant synergies outside of the core technologies, and these synergies provide an opportunity for BETO to have a positive impact to the industry at large. The Panel identified three areas with significant potential synergies: biomass handling/preprocessing, fuels qualification, and identification of market opportunities. Handling and sizing biomass has been a significant challenge for most of the industry participants to date; some investments in R&D at equipment vendors could enable single investments to benefit multiple projects. Additionally, different plants that use the same equipment tend to form working groups to share knowledge on the best ways to operate and maintain the equipment. This accelerates the maturation of the technology, increasing the availability of the projects and, ultimately, their profitability. While we did note that BETO team members informally worked to capitalize on the synergies between the projects in the portfolio, the Panel thought that it may be beneficial to establish more formal links between projects with potential synergies. For example, the Brookhaven National Laboratory Bio-Oil Deployment in the Home Heating Market project identified a large market with lower barriers to entry, but the success of the project was limited due to the unavailability of bio-oil for testing by potential off-takers.

Focus

If at all possible, the Panel would like to see DMT fund some additional projects, as there are many more potential technologies in the space, and the two current projects only cover a small portion of the total. In the plenaries, the DMT team noted that six additional projects were awarded grants under the PD2B3 FOA, and that the DMT team would like to extend additional awards under the IBR Optimization FOA in 2017. We support the replenishment of the portfolio and commend the DMT team for funding these new projects. In addition to the aforementioned investments, the Panel believes that some focused investments in biomass preprocessing and fuels qualification could potentially assist a number of companies in the space.

Commercialization

The Panel noted that one of the key commercialization metrics is availability, and that the best way to identi-

fy items that reduce availability is to operate plants for extended periods of time. The Panel thought that more focus on the operation of existing assets, rather than construction, may allow BETO to stretch their budgets in this area. For example, the Panel thought that Mercurius' revised plan to utilize existing assets at Michigan State University's Bioeconomy Institute rather than constructing them for the project would have been a more rational and cost-effective approach if done at project inception.

The Panel also noted that it may be beneficial for BETO to favor those pilot plants that will be operated for more than 1,000 hours. While 1,000 hours is generally viewed as sufficient to achieve stable operation and derive useful data on the yield of the process, this amount of time is insufficient to identify long-term operations and maintenance issues that would be encountered at commercial scale. In the absence of a demonstration-scale plant in between the pilot and commercial scale, successful developers like POET-DSM's Project LIBERTY have operated their pilot plants for tens of thousands of hours to identify and correct these issues. While we acknowledge the criticality of the pilot plant testing, we do also acknowledge that certain unit operations cannot be properly tested at pilot scale due to differences in functionality and operating characteristics; thus, testing at or near full scale is a commercial reality for developers in the space.

Recommendations

When asked to identify the three most important recommendations that would strengthen the DMT portfolio, the Review Panel has the following recommendations:

Recommendation 1: More Funding for DMT Projects

Getting more sufficiently funded projects into the DMT portfolio will be key, as it is likely that not all of them will be successful. Acknowledging that these projects are expensive, it is critical to have a sufficient number so that there are enough successful outcomes so that taxpayers can see a return on their R&D investments. Additionally, we note the criticality of proper funding/resourcing of the projects, as dividing the existing limited budget on an increased number of projects could result in under-resourced projects with bad outcomes.

Recommendation 2: Focus National Laboratories' Efforts on Availability Issues (versus yield) outside the Core Technologies

Efforts such as the ORNL Fire Standards Codes and Prevention in IBRs project and the Idaho National Laboratory biomass handling assistance to DuPont have the potential to dramatically increase the success rate of individual technologies while having a positive impact industry-wide.

Recommendation 3: Develop FOAs that Use Existing Assets for Testing and Test for Longer Periods

"Capital-light" approaches with existing assets reduce the amount of resources spent developing a green field space and can yield more rapid results than projects that include construction.

DMT PROGRAMMATIC RESPONSE

Introduction/Overview

BETO would like to thank the Review Panel for their time and active participation in the DMT session, as well as the panelists and Steering Committee for providing their feedback during the Project Peer Review meeting in March 2017 and the Program Management Review meeting in July 2017. We appreciate the Panel's insightful and engaged review of the DMT projects. The reviewers all provided in-depth and constructive recommendations that can be used to inform the DMT Technology Area's path forward in the coming years.

At the 2015 Peer Review, the DMT session Review Panel reviewed a total of 19 projects from the DMT portfolio. Many of these projects were funded through the American Recovery and Reinvestment Act of 2009 and were completed prior to the 2017 review. In 2017, the Panel reviewed four projects. Two of these were IBRs, and two were market transformation–focused projects from the national laboratories. BETO would like to thank the PIs for taking the time to present their findings and progress and for their hard work in executing these innovative projects.

At the 2015 Peer Review, reviewers provided the following recommendations to the DMT Program:

- Increase the DMT portfolio's diversity and funding level—this is essential to maintain the momentum established thus far and to show commitment to developing technologies
- Focus on primary products that are not fuels
- Give consideration and preference to projects that co-locate with existing facilities, based on potential benefits of co-location
- Consider a break-even scenario, instead of positive cash flow, for pioneer commercial-scale projects
- Continue to support promising American Recovery and Reinvestment Act projects.

The DMT Program has made efforts to incorporate these recommendations into its actions over the past 2 years, and since the 2015 Peer Review, we have released two FOAs. These FOAs are geared toward furthering the commercialization of biofuels through supporting pilot- and demonstration-scale facilities and biorefinery optimization in order to lower the technical and financial risks facing IBRs. The 2017 Review Panel noted that the DMT portfolio was smaller than in years past, but the Panel recognized that these recent FOAs will expand the portfolio significantly.

The Panel commented on the significant impact that the DMT portfolio has had on the commercialization of biofuels both through the POET-DSM biorefinery and through market transformation projects, such as ORNL's Fire Standards Codes and Prevention in IBRs. The Panel said that the POET-DSM LIBERTY demonstrated the viability of a commercial-scale facility and that its learnings will drive further R&D. The ORNL work is addressing an industry-wide issue, as nearly every IBR has experienced a biomass fire in some capacity. The Panel believes that, in the context of commercialization, it is important that future pilot plants are operated beyond the current goal of 1,000 hours, as existing facilities are still experiencing issues with continued operation. DMT supports this point and agrees that reliable, continuous operation is necessary for the commercialization of biofuels. We appreciate this feedback and are working to address this point through current and future plans.

The PD2B3 FOA incorporated language that set aside funding specifically for testing facility operation at pilot- and demonstration-scale biorefineries. The recent IBR Optimization FOA focused on enabling the reliable and continuous operation of biorefineries. These two funding opportunities will work to address areas identified by the Panel, but DMT will continue to support commercialization of biofuels and bioproducts in future planning.

Although the 2017 DMT portfolio was smaller than in years past, the Panel recognized that is was growing again and had incorporated a strong innovative technology investment strategy that included both breadth and depth. The Review Panel also commended BETO's stage-gate review process in that it rewards progress rather than effort. This pushes projects to grow while also reducing unnecessary spending. DMT's adherence to active project management procedure and stage-gate reviews ensure that projects do not receive funds prematurely. This process protects taxpayer funds and ensures that all projects are managed uniformly. DMT will continue to adhere to active project management procedure in future projects but will also take additional steps to validate biofuel technologies prior to project kickoff. These steps will further ensure that DMT funds are well-managed and support technologies that have a greater chance of success.

The Panel said that one of DMT's stronger areas was its synergies with the biofuels industry, particularly in biomass handling and preprocessing, improvement of conversion yields, fuels qualification, identification of market opportunities, and assistance with financing challenges. The Panel stated that while BETO works informally to capitalize on synergies within the program, it may be beneficial to establish more formal links between BETO projects. BETO and the DMT Program recognize the potential for greater collaboration between existing projects and will consider incorporating this this as we develop future plans for both competitive and non-competitive funding. The Feedstock-Conversion Interface Consortium is also a strong example of where future synergies between stakeholders and projects can be developed.

The Panel concluded that one of the greatest limitations to DMT achieving its goals is the program's funding level. While the Panel recognized that DMT's funding may be outside of its control, they proposed ways that DMT could use existing funds to their greatest potential. This point was also included in their overall recommendations, and the Panel recommended that the program could manage to support the industry despite limited funding by promoting projects that utilize existing assets and infrastructure. By utilizing existing infrastructure, the capital necessary for a project could be dramatically decreased. We recognize the limitations of a decreased funding level as it applies to all projects, especially those with a capital-intensive construction phase, and appreciate the Panel's insight into how we can continue to impact biofuels commercialization at any level of funding. DMT will consider implementing this suggestion for future opportunities.

In addition to program-specific feedback, the Review Panel provided project-specific feedback. The PIs and their project teams will work to incorporate this feedback as they continue forward with their projects.

To conclude its review, the Panel provided three overall recommendations for the DMT Technology Area that, if implemented, would have the greatest impact on the portfolio and its ability to achieve its goals:

Recommendation 1: More Funding for DMT Projects

The Panel recommended awarding a greater number of DMT projects based on the knowledge that not all projects will be successful. While recognizing that DMT projects tend to require greater levels of funding than initial R&D, the Panel recommended that the DMT portfolio house more projects to ensure a greater probability of successful outcomes. This approach would ensure that the biofuels industry continues to move forward under government support and that taxpayer funds are providing a return on R&D investments.

DMT agrees that by both expanding and diversifying its portfolio, biofuels and bioproducts could see a greater number of successes, which in turn decreases risk to private investment, further supporting the industry. We greatly appreciate this recommendation and, while the DMT portfolio continues to expand under recent funding opportunities, we will continue to prioritize this growth in future plans.

Recommendation 2: Focus National Laboratories' Efforts on Availability Issues (versus yield) outside the Core Technologies

The Panel's recommendation to focus national laboratory efforts on availability issues arose from the impacts of efforts such as ORNL's Fire Standards Codes and Prevention in IBRs project and Idaho National Laboratory's biomass handling assistance to DuPont. These efforts have the potential to dramatically increase the success rate of the individual technologies while having a positive impact industry-wide. In addition, these projects have historically required less funding than a biorefinery project, and their findings benefit projects across the industry. Since national laboratory projects can also be funded non-competitively through annual operating plans (AOPs), this gives BETO and the laboratories the ability to tailor projects based on new findings on a shorter time scale than issuing a new FOA would require.

DMT's work with the national laboratories has produced far-reaching benefits for the biofuels industry. DMT

recognizes the strength of the national laboratories and aims to continue utilizing them in future work. ORNL's Fire Standards Codes and Prevention in IBRs is a great example of a project outside of core technologies that has had a large impact industry-wide, and DMT will consider implementing similar projects in the future.

Recommendation 3: Develop FOAs that Use Existing Assets for Testing and Test for Longer Periods

While the Review Panel noted that DMT would require greater funding levels to grow its portfolio, they also recommended "capital-light" approaches that the program could incorporate in order to have a continued impact without relying on high levels of funding. The Panel recommended that DMT select projects that utilize existing assets to reduce the amount of resources spent developing a green field space. These projects can yield more rapid results by utilizing existing assets.

Additionally, the Panel recommended that the DMT Program extend its current goal of 1,000 hours of operation for a pilot-scale biorefinery. The Panel noted that as more companies tend to skip the demonstration-scale phase, they are losing important operational data that extended operations could provide. For example, POET-DSM's pilot facility has been run for tens of thousands of hours and has provided critical data that can further inform commercial-scale operation.

DMT agrees that the data collected through pilot- and demonstration-scale operation of biorefineries is critical to identifying and mitigating issues that will arise at commercial scale. As operation of these facilities can be expensive, some projects choose to abandon smaller-scale operations after 1,000 hours as a cost-saving measure, which may ultimately cost the project more in the long run. As mentioned previously, the PD2B3 FOA will hold a set amount of funding aside specifically for testing facility operation at pilot- and demonstration-scale biorefineries. This may help mitigate the issue of projects scaling up prematurely due to limited funds. The recent IBR Optimization FOA is also focused on enabling the reliable and continuous operation of biorefineries, which will ultimately help these projects run for extended periods and allow them to collect the data necessary to inform a successful scale-up. DMT agrees with the Panel's recommendation and will consider implementing it further in future work.

As mentioned in previous sections, BETO will consider the Panel's recommendations and incorporate them, as appropriate, in program elements and future funding opportunities. The DMT team will also coordinate with the Feedstock-Conversion Interface Consortium to assess the potential for implementing some of the Panel's recommendations for greater synergy among projects.

BETO, the DMT program manager, and the DMT technology managers would like to thank the Review Panel for their time and their engaged review of the BETO's DMT Program. The Panel's comments were largely positive and provided the program with the type of actionable feedback that can help promote progress towards the development of commercially viable bioenergy technologies.

FIRE STANDARDS CODES AND PREVENTION IN IBRS

(WBS #: 3.1.3.2)

Project Description

The project's goal is to work with industry partners to develop and refine industry codes and standards to facilitate industry expansion while (1) protecting people and assets from fire and (2) expanding business opportunities by meeting sustainability expectations. Working with industry stakeholders in the Biomass Industry Panel on Codes and Standards, the project team conducted experiments to determine appropriate classifications for corn stover and switchgrass in the National Fire Protection Association Sprinkler Discharge Standard.

Future work is also underway to (1) develop a guideline document to explain relevant building and fire codes for engineers and code reviewers developing new biomass-handling facilities, and (2) design experiments to determine parameters for designing safer outdoor biomass storage facilities.

Recipient:	Oak Ridge National Laboratory
Principal Investigator:	Erin Webb
Project Dates:	10/1/2014–9/30/2017
Project Category:	Ongoing
Project Type:	AOP
Total DOE Funding:	$1,220,000

Responding to industry concerns that current sustainability standards do not provide adequate guidelines to support fair and consistent comparisons, the ORNL project team helped form a committee of industry stakeholders to develop the new ASTM International "Standard Practice for Assessment of Relative Sustainability." Following unanimous approval of the new Standard Practice, work is underway with industry partners to deploy and test it.

Weighted Project Score: 7.9

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

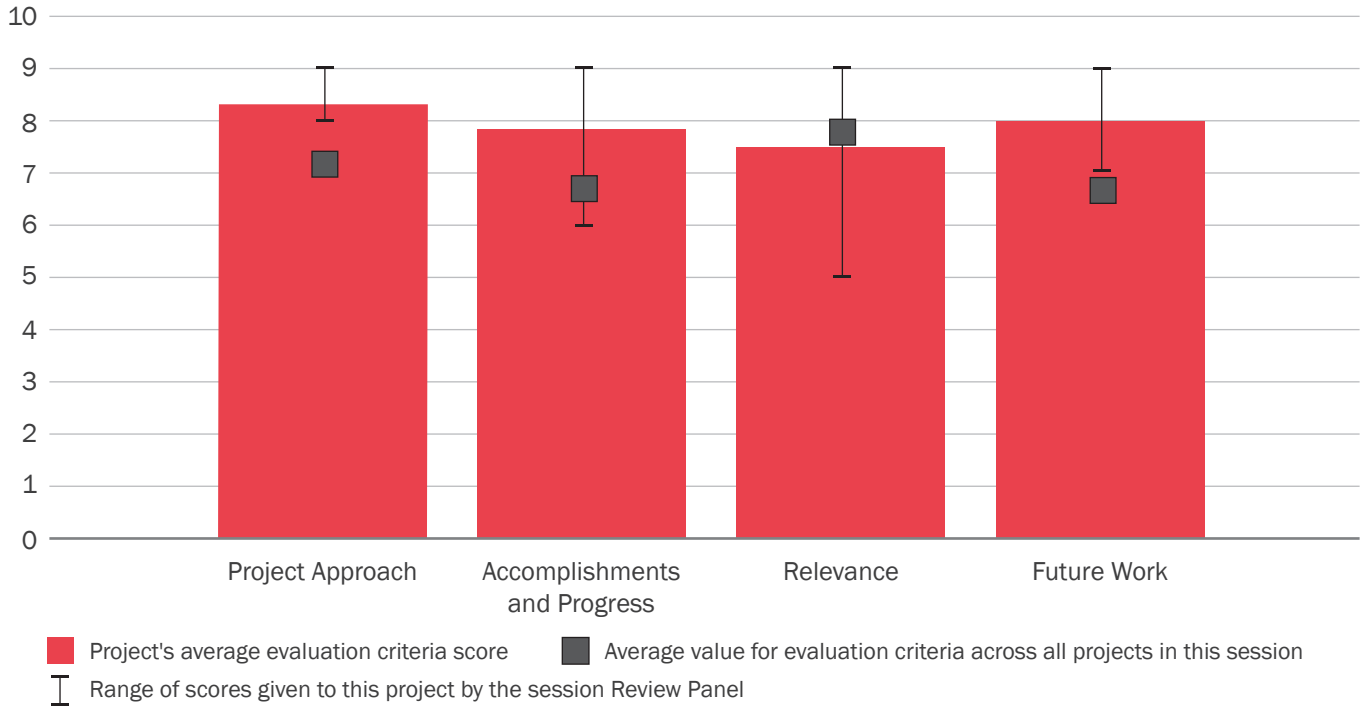


Photo Courtesy of Oak Ridge National Laboratory

Overall Impressions

- My overall impression is that this has been a well-run project and is providing meaningful results. The only minor criticism is that the cost of planned work should have been estimated and built into their presentation, so we could see if they are on track to complete the project, but overall, this is well-done.
- The presentation overall was well-done. The topic is very useful to the industry to reduce risk and provide guidelines for storage of feedstock. More work on additional fire classification of feedstock would be useful overall. If possible, being able to model future feedstock storage guidelines based on the material heat of combustion, bale shape, density, and storage stack shape and size could be very useful for reducing fire risk for many industries utilizing biomass.
- This is an excellent project and represents important work to better understand biomass fire risk and develop best industry practices for biomass storage facilities. The project team did a great job leading and facilitating industry-backed committees to address scale-up barriers in the biomass supply industry. It would be nice to see further DOE-funded work to address fire ignition sources and how to prevent widespread dissemination of fires.
- This is a highly relevant project that can be streamlined to have a greater impact to the overall industry. Testing could be more focused and have a clearly quantified financial benefit/analysis tied to various scenarios. This would be helpful in allowing the industry to evaluate different options and would likely lead to a greater impact on the industry. The Biomass Industry Panel on Codes and Standards should be leveraged in deciding what future testing should be done and where the greatest need for additional codes is (various feedstocks, etc.).
- The standard development for fire prevention is a tangible and valuable asset for industry trying to utilize two of the top farm-based cellulosic feedstocks, switchgrass and corn stover. The results have been interesting to date and are already useful for planning layouts and providing additional direction to feedstock baling best practices and equipment design in the field.

  Although it was a small part of the overall budget of this project, as written, the sustainability standard does not appear to address a gap or need to the industry. The specification does not appear to provide additional value over basic project management standards (e.g., identify stakeholders, have a communications plan).

  The team is ahead of schedule and within budget. The team is executing the plan it set out to do and does not appear to have run into any technical or project management challenges. Overall, this is a good project that is being well-run.
- Overall, this work is to fill a very important gap in industry knowledge and allow industry participants to focus more on their core processes, rather than learning on the job. It was nice to see the approach of doing actual burn tests to generate real data on the matter.

PI Response to Reviewer Comments

- Tasks on ASTM International and fire codes are combined because (1) both tasks support market demonstration goals; (2) they address common BETO barriers (high risk of large capital investments; codes, standards, and approval for use; and lack of acceptance and awareness of biofuels as a viable alternative); and (3) the combination generates synergies and more-efficient management of scarce resources. Counterparts and researchers under each task have provided mutually beneficial information to the other task.

  As recommended, the ASTM International task is being revised to respond to industry priorities and address the clear and present danger to U.S. trade ($3 billion/year in ethanol and pellets) created by a potential loss of market access due to non-tariff barriers in the form of sustainability standards. The ASTM task is founded on industry requests to fill gaps that address relevant trade barriers to biobased U.S. exports.

  The next issue to be addressed is the definition of a counterfactual or "reference" case. Biased depiction of a reference case has been instrumental in justifying proposals in several European nations to ban U.S. wood pellets ($1 billion per year of U.S. exports). We propose to continue collaborations with ASTM and industry to ensure that the investments made to develop ASTM E0366 achieve lasting and valuable impacts for the U.S. economy.

RENEWABLE ACID-HYDROLYSIS CONDENSATION HYDROTREATING (REACH) PILOT PLANT

(WBS #: 3.4.1.19)

Recipient:	Mercurius Biofuels
Principal Investigator:	Karl Seck
Project Dates:	9/30/2013–12/31/2016
Project Category:	Ongoing
Project Type:	FY 2013—IBR iPilot: DE-FOA-0000739
Total DOE Funding:	$4,684,619

Project Description

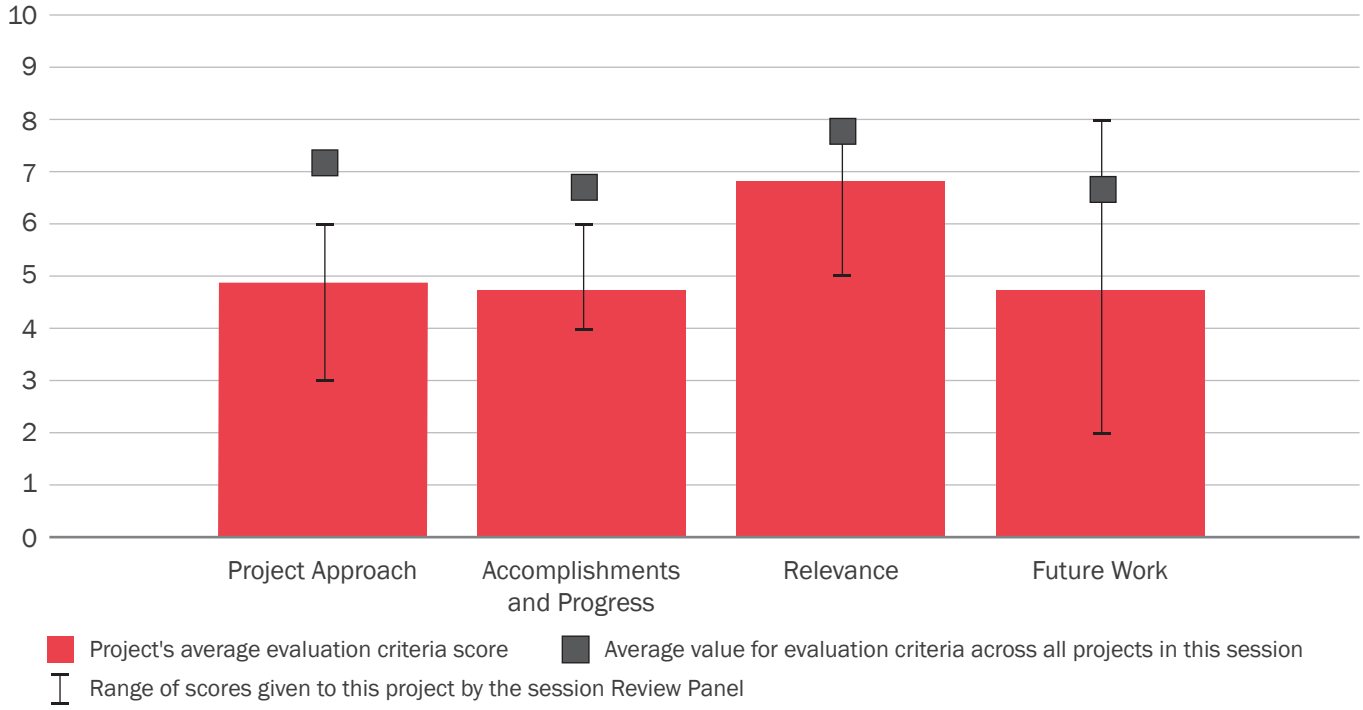
This project's goals are to design, build, and operate a pilot plant to scale up the Mercurius REACH process. The REACH process is a novel technology that efficiently converts cellulosic biomass into drop-in hydrocarbon jet fuel and diesel. This process aims to provide an economically viable technology to start building cellulosic biofuel capacity for Renewable Fuel Standard mandates, as well as to compete with petroleum economics down to $40/barrel of crude. The REACH technology is based on acid hydrolysis to non-sugar intermediates, such as chlormethylfurfural (converted to other compounds). The greatest technical and non-technical challenges facing this project are acid recovery/recycle, product quality, techno-economic validation, and investment funds for further work and operations.

Overall Impressions

- Raising money is extremely difficult in the current environment. This project perhaps highlights a need for matching funds to be in place prior to award, or to be required within some set number of months of the award, prior to starting the project. The technology looks promising, but without the funds necessary to execute it, we may never know.

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.



- The technology appears to be in the early phase of development, and the recipient may have been closer to bench/small process development unit scale rather than pilot scale when the grant was received. The presenter is optimistic about potential issues, beyond acid hydrolysis. It has yet to be seen whether this small business project team has the depth meet the funding requirements for advancing to Budget Period 2 by the end of the no-cost extension. The cost metrics looked good, but it was unclear if the metrics had been refined with information gleaned over the course of the project.
- The project offers an innovative technology with the potential to be a game-changer for the cellulosic biofuel industry. More R&D work may be needed before the project is ready for a larger scale, particularly on the front end of the process. The project has had difficulty fundraising, and the future of the project is in jeopardy.
- This project is complicated and will require strong project management skills and discipline to be successfully executed. While the current approach may save immediate capital requirements, it does so by adding to the risk of cost overruns and schedule delays because it lacks an integrated bench-scale facility. The PI may want to consider partnering with a strong strategic investor to ensure the technology can be demonstrated successfully, or re-scope the project to something smaller and more focused. BETO should require that a binding recovery plan be agreed upon between the parties before continuing to fund this project.
- The project appears to be caught between a fundraising rock and a cost-of-engineering hard place. Like all projects in its portfolio, this project has technical risks, and DOE and BETO are right in holding firm to the contingency level required for this project.
- Overall, the REACH technology represents an innovative approach that has the potential to reduce the capital costs of cellulosic fuels facilities. The project is certainly unique within DOE's conversion portfolios, and it is nice to see DOE support some of the out-of-the-box technologies. The project is currently behind schedule, and completing the project in a timely manner will be very difficult. Absent a very detailed plan/schedule on how the project is to complete its work, there is a risk that the Budget Period 2 funds could be exhausted without advancing the technology.

PI Response to Reviewer Comments

- Regarding the contingency requirement, it is Mercurius' view that the required contingency should be based on a risk assessment of the specific project and be a shared requirement per the cost share of the grant.
- Regarding the need for more R&D work, the acid-hydrolysis step of our process has been thoroughly investigated at a bench scale. Hundreds of runs have been made by multiple labs. It is our opinion that we have done sufficient R&D on the front-end process.
- General: Other comments seem to assume everything would be fine if we just made better plans or used better project management techniques. This might be a good answer on a test in business school, but it is not the answer to all problems in the real world. It is certainly not the solution to delays in this project. As commented in another section, the problem is funding and managing laboratory sub-recipients that have to supply dollar-for-dollar cost share. Project management techniques that are designed for capital projects and large, well-funded bench-scale investigations do not translate very well to the front end of our project.

  All this being said, I realize that the reviewers are put in the difficult position of evaluating a complex project with only a little information (nothing proprietary) in a short period of time.

LIBERTY—LAUNCH OF AN INTEGRATED BIOREFINERY WITH ECO-SUSTAINABLE AND RENEWABLE TECHNOLOGIES IN YEAR 2009

(WBS #: 3.4.3.3)

Recipient:	POET-DSM
Principal Investigator:	Mike Dishman
Project Dates:	10/1/2008–12/31/2017
Project Category:	Ongoing
Project Type:	FY 2006—IBR Section 932 FOA: DE-PS36-06GO96016
Total DOE Funding:	$87,844,240

Project Description

POET-DSM's Launch of an Integrated Biorefinery with Eco-Sustainable and Renewable Technologies in Year 2009 (LIBERTY) is dedicated to the development and operation of a commercial-scale cellulosic ethanol biorefinery.

The plant is co-located with POET Biorefining – Emmetsburg, an existing corn-based ethanol biorefinery in Emmetsburg, Iowa. The corn-based biorefinery currently has a name-plate capacity of 50 million gallons/year and is one of 27 POET biorefineries. At full capacity, Project LIBERTY will produce an additional 25 million gallons/year of cellulosic ethanol from a feedstock of lignocellulosic material, i.e., corn cobs and high-cut material from the corn plant. Corn farmers from the surrounding area supply the feedstock to the biorefinery. The Project LIBERTY business model will enable rapid deployment of the cellulosic ethanol process across an expansive corn ethanol industry. The rollout of LIBERTY technologies will help the nation rapidly advance toward its biofuels mandates and reduce its dependence on foreign oil.

Weighted Project Score: 7.7

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

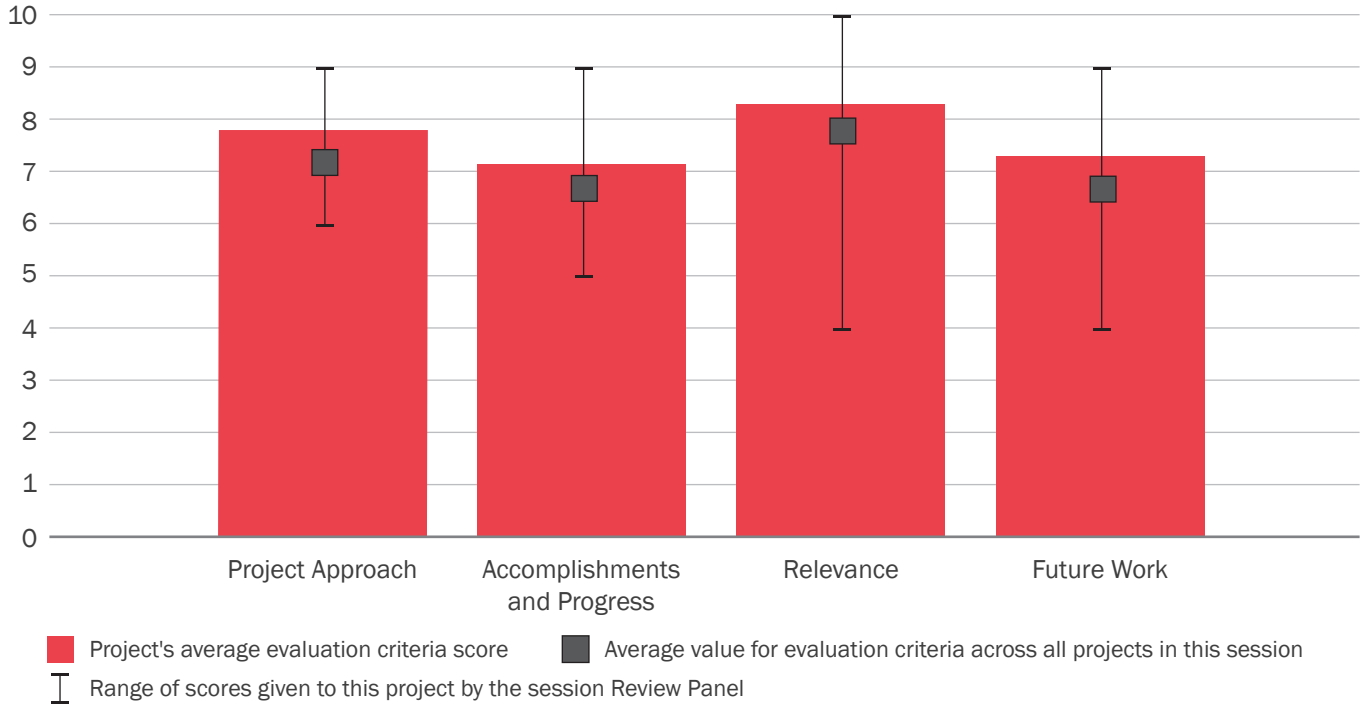


Photo Courtesy of POET-DSM

Overall Impressions

- Even at their goal of $10/annual gallon, the future economics hinge on Renewable Identification Numbers. That seems like a shaky economic proposition at this point. Overall, though, the project has attained most of its goals and has been well-run. I hope they can soon solve their remaining technical challenges and reach sustained design output, and then get on with a second plant (and a third).
- Given the overall timeframe for the project and development along the way, this appears to be a well-run project. It would be of interest to have more information about the project's challenges as a lesson(s) to other projects to follow in order to promote the success of the biofuels industry overall.
- The success of this project is critical for advancing the state of the biofuel industry. I am optimistic that the project's start-up challenges will be resolved and that the plant will achieve design capacity.
- It is not clear that this is a financially viable project or one that could be duplicated. The project shared very little information on challenges it is encountering. The overall industry would benefit from lessons learned being shared, especially pertaining to equipment or processes that are common/not proprietary, driving down the costs for the industry as a whole. The project based much of its operational plan on its experience at the pilot-plant level; however, comparisons of commercial-plant versus pilot-plant results were not shared. It would be useful to understand what, if any, benefit the project would have had in building a demonstration-scale plant and if the costs of doing so would be less than the costs being encountered to overcome some of the challenges in ramp up (this would be helpful for smaller companies in evaluating the benefits of building the demonstration-stage plant or not). Feedstock handling remains a major industry challenge (including to POET), and it would be useful if the project would share its lessons learned and collaborate with other companies to help overcome this common challenge. I believe the economic viability of POET's process would be realized through collaboration.
- POET-DSM's Project LIBERTY has successfully built a cellulosic ethanol facility using their technology. They have proven that their technology can produce ethanol from corn stover. However, they have not yet proven the availability of the system or the commercial viability of the technology. These are two key drivers of any future plant.

  POET-DSM should be congratulated for continuing to persevere in the face of startup headwinds. We all hope they achieve commercial success.

  Once POET-DSM achieves commercial operations, it will be a star project for DOE and BETO to point to in order to display the impact that they can have on pushing new technologies to commercial viability. The POET project would not have been successful if it were not for DOE's support.
- Overall, this is a very impressive project that was made possible with BETO support. As potentially the first large-scale commercial biorefinery to enter into normal production, this plant could open the

next chapter in the biorefining industry. Both BETO and POET should be proud of their accomplishments here; the number of jobs created in rural areas could be a game changer for the U.S. economy.

PI Response to Reviewer Comments

- POET-DSM believes our advances in the challenges to the cellulosic biofuel industry will propel the industry forward. We know our process works and believe the United States and the world will become invested as we continue to prove cellulosic biofuels are no longer a fantasy fuel.

BROOKHAVEN NATIONAL LABORATORY BIO-OIL DEPLOYMENT IN THE HOME HEATING MARKET

(WBS #: 5.3.0.1)

Recipient:	Brookhaven National Laboratory
Principal Investigator:	Thomas Butcher
Project Dates:	10/1/2013–4/30/2016
Project Category:	Sun-setting
Project Type:	AOP
Total DOE Funding:	$1,150,000

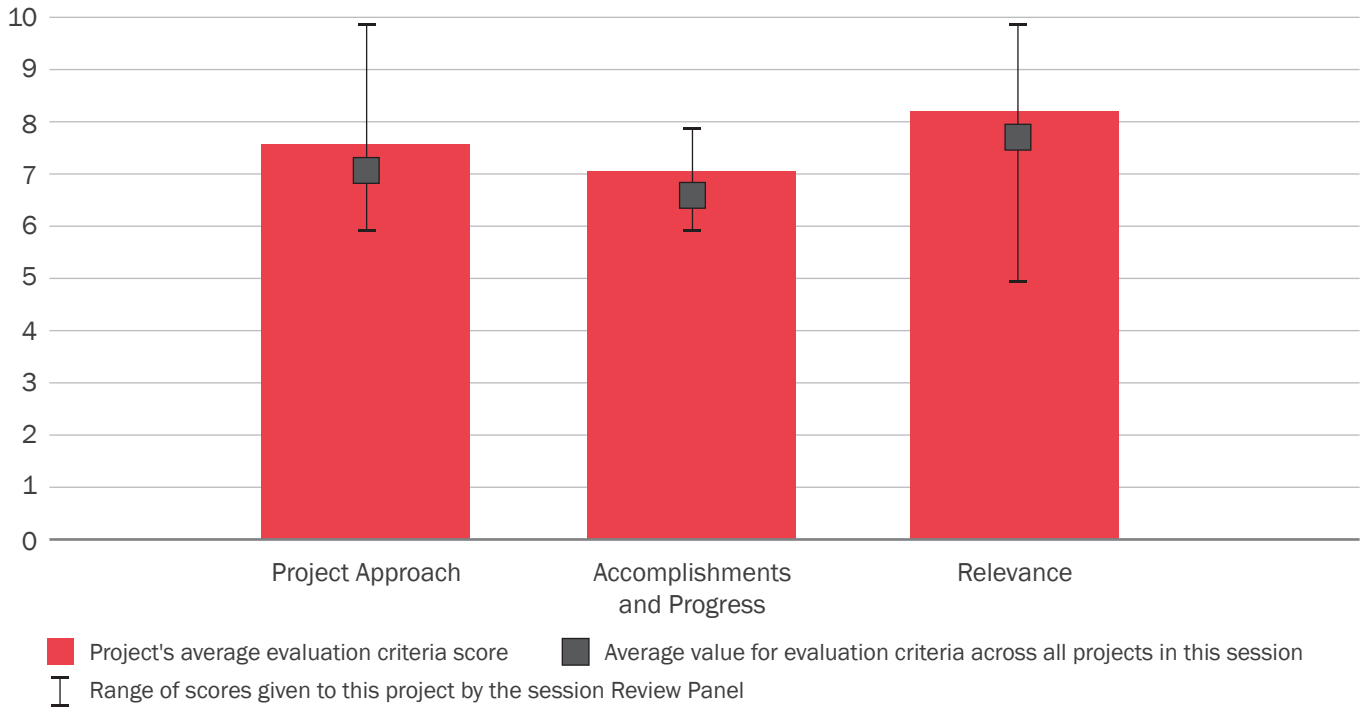
Project Description

The heating oil market represents a potential early market entry point for emerging, near-commercial, upgraded bio-oils. This project is focused on identifying commercial projects, which may provide fuels for this market and provide technical evaluation of the use of these fuels in heating oil blends. Distillate heating fuel is widely used, mostly in the Northeast. Non-transportation distillate use was 10.9 billion gallons in 2014.

This study has focused on displacing part of heating oils with upgraded pyrolysis oil. The quality of these fuels is affected by process conditions, and there is a cost/quality trade-off. Partially upgraded fuels may be the economical compromise—containing residual oxygenates but still providing good performance in use. The focus of this work has been on fuels that can be blended at a minimum of 20% and used without changes to equipment. We studied four different biofuels, from minimally upgraded to fully upgraded. We also conducted combustion testing in both a quartz chamber and a heating boiler. The lowest quality fuel was fired without blending. The combustion quality of all tested fuels was acceptable.

Weighted Project Score: 7.6

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



Research included compatibility of the test fuels with elastomers used in these applications. Elastomer swell was unacceptable with some fuels. Storage stability was also found to be poor except in fully upgraded fuels. We completed synthetic bio-oil blend studies in which specific oxygenates were added into petroleum fuel. The oxygenates were shown to increase elastomer as well. The addition of phenols increased the production of filterable insolubles in storage. A route to use of such bio-oils involves developing a storage stability performance–based specification. Overall, the study indicates strong potential for this fuel in this market.

Overall Impressions

- This was a good first step if the results, which seem preliminary, meet the stated goals. If the ASTM standards can be established, then the next obvious step is to look into economics, both from a supply and demand side. Producing pyrolysis heating oil to the ASTM design standards may be costly, so that needs to be investigated soon if this is to be a viable industry.
- The presentation and work were very well-presented. It is unfortunate that more samples were not provided for testing. However, the work provided a path for testing that must be considered for future biofuels that might be utilized for the home heating oil industry.
- This project has demonstrated technical feasibility of using renewable oil in the home heating oil market. Unfortunately, the scope of the project was modified as a result of bio-oil producers' reluctance of to supply fuel samples. Further work is needed in establishing/updating ASTM specification to give producers a target to achieve. There is an opportunity for BETO to support future work in this area, including testing of long-term storage stability and standards modification for this application. Focus should be made on ensuring fuel producers will be engaged in the project prior to award.
- This project could have significant impacts to the overall bio-industry (love the goals, etc.). However, the specifications and standards must be developed (meaning that more testing of actual available fuels needs to occur). It would be helpful to see what other arenas (besides the National Oilheat Research Alliance) could be taken to market the project to industry stakeholders. Besides standards, economic analysis for producers and consumers would provide something tangible in lieu of having an actual product for consumers and may provide more valuable feedback into where future work needs to occur.
- The project appears to be well-run despite having faced a severe hurdle in gaining interest from industry.

  The project raised almost as many questions as it answered—which is good from a scientific perspective, but frustrating from a program development perspective. The results from this project appear to be a useful step in developing the renewable home heating oil market, but they are not sufficient to have completed the task of making this market viable. Further testing is needed to obtain ASTM certification for these fuels in this market.

  The relevance of this market is larger than expected. The market for this project is almost as large as the corn ethanol industry's current output.
- This is a very interesting project, to open up a large and potentially easier market to enter. For future work within BETO, it may be helpful to identify where the test volumes are to come from at the beginning of the project so that resources can be added to generate test volumes if they are not available via the private sector.

PI Response to Reviewer Comments

- Establishing an ASTM spec for a low but not trace-level oxygen content bio-oil that is fully miscible with petroleum-based home heating oil is

a good next step, assuming the fuel producers want to introduce such a fuel into the market. The fuel producers should participate in this process, along with burner and component manufacturers, as part of ASTM because it will be an iterative process. If the route is taken to define such a new fuel, a next step will follow under which equipment manufacturers will need to develop and list new products compatible with this new fuel. A "limit" fuel will need to be defined with more adverse properties than the specification fuel for the purpose of running the listing tests. This would include, for example, elevated total acid number to reflect the worst that would be expected in the field.

We fully agree that long-term storage stability testing needs to be part of future work, and a long-term storage stability specification needs to be included in the ASTM specification.