BIOENERGY TECHNOLOGIES OFFICE (BETO)



Energy Efficiency & Renewable Energy



Moving Beyond Drop-In Replacements: Performance Advantaged Bio-Based Chemicals July 11, 2017

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BETO funds R&D for renewable fuels and chemicals

- Biomass is a great domestic resource; 1 billion tons of sustainably produced non-food biomass available by 2040
- Biomass is a source of renewable carbon, can be converted into renewable fuels and products
- Goal: Demonstrate \$3/gge hydrocarbon biofuel with >50% GHG reduction



Renewable Energy

The petroleum industry relies on chemicals to supplement fuel production... does this strategy make sense for the biofuels industry?
 Source: Bloomberg New Energy Finance, EIA, American Chemical Council

Why is BETO interested in biobased products?



Source: Ryan Davis, NREL, 2017 Peer Review Presentation



A Decade+ After the Top Value Added Chemicals...

Top Value Added Chemicals from Biomass Volume I—Results of Screening for Potential Candidates from Sugars and Synthesis Gas

> Produced by the Staff at Pacific Northwest National Laboratory (PNNL) National Renewable Energy Laboratory (NREL) Office of Biomass Program (EERE) For the Office of the Biomass Program T. Werpy and G. Petersen, Editors

- In 2004, DOE published the first volume of the Top Value Added Chemicals from Biomass; several updates since
- Predicted commercially successful biobased chemicals such as succinic acid
- >215,000 downloads, >1800 citations; revisited by Biofuels Digest, C&E News, etc.
- Gave academics and small companies focus, helped corroborate business plans
- Available on our website

What will the next report look like?

Can BETO produce a strategic plan or other document that aids bioproducts R&D in the same way that previous "Top 12" reports have?



Definitions

- **Drop-in replacement:** a bio-derived compound that is chemically identical to its petroleum counter part
- Functional replacement: a bio-derived compound that has a different chemical structure than a petroleum counter part, but performs the same function/has the same performance attributes
- Performance advantaged bio-based compounds: a bio-derived compound that does not resemble an existing petroleum-derived compound in structure, function, or performance attributes. The bio-based compound offers novel functionality or improved performance attributes.







Get stakeholder input on:

- What are the challenges in identifying and developing novel performance advantaged biobased chemicals?
- What are the strategies for tackling these challenges?
- If there was a concerted R&D effort in this area, what considerations do you think are most important?

Determine a path towards:

- Producing a strategic plan for performance advantaged bio-based chemicals
- Providing a repository of useful, fully characterized, bio-based compounds with known properties for consumer use
- Providing a publically-accessible high-throughput screening facility for identifying bio-based functional replacements and novel products



Why Pursue Performance Advantaged Biobased Chemicals?



Product Design Benefits

- Biomass contains functionality not present in other feedstocks
- Opportunity to design and bring new products to market



Economic Benefits

- Increase value of domestic feedstock
- Provide source of revenue for existing biorefineries



Environmental Benefits

- Potential for lower toxicity
- Reduced life cycle impact (biodegradability/recycl ability)





What are the biggest challenges to achieving these benefits?





Target Identification:







Target Identification:

- Solutions
 - Identify key performance characteristics for screening and selection
 - Develop a system to link molecule producers with end users





Technology Development:





Technology Development:

- Solutions:
 - Create open libraries of data
 - Develop a centralized coordinated center to develop knowledge base around these areas
 - Additional funding for technology development









End Use:

- Solutions:
 - Bridge early technology to end use
 - Improve infrastructure for scale-up, and increase understanding of physical and biochemical science when moving to scale





Market Acceptance:





Market Acceptance:

- Solutions
 - Focus on reports and other **public campaigns** to increase awareness
 - Facilitate more communication between researchers, industry, and consumers
 - Develop a set of universal standards





Survey Results

Would you use a research center/facility that was targeting the identification, synthesis, and testing of novel biobased compounds?





- How can BETO best facilitate conversations between end-users and scientists?
- Is there a finite set of metrics/properties/specifications that could be screened for if a high throughput screening facility was developed?



Thank you!





Biobased products contain oxygen... like biomass



Vennestrøm, P.N. R. et al Angew. Chem. Int. Ed. 2011, 50, 10502-10509

Shen, J. et al Energy Conversion and Management **2010**, 51, 983–987



Case study: Replacing BPA



 $(C_{15}H_{16}O_2)$

•High production volume chemical

•US market 2.2 billion tons, \$2 billion (2007) (source: EPA Action Plan for Bisphenol A 2010)

- •Plasticizer for polycarbonate plastics
- Potential for health issues; banned in many countries
 Bisphenol A was first synthesized in 1891; In commercial use since 1957



•EPA report on BPA alternatives, 2014

•Bio-derived, bio-degradable, non-toxic

Researchers have shown that isosorbide is a suitable functional replacement for BPA; commercially available as a BPA replacement
Would never synthesize this from a petroleum-derived starting material

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22 | Bioenergy Technologies Office

Case study: Replacing BPA

- It is difficult to determine from visual inspection what makes a good functional replacement.
 - How do you systematically identify replacements and novel chemicals?
- We are limited by traditional chemistry, traditional feedstocks, and risk adversity
 - What are the risks associated with new introducing new feedstocks and chemicals that should be addressed early on?
- Society has an appetite for improved materials with enhanced or novel performance attributes
 - What performance attributes should be tested for?
- The next BETO bioproducts R&D plan should focus on novel, biobased chemicals that are not easily identified and offer enhanced performance attributes

Is isosorbide a functional replacement?



Bioproducts Can be Integrated into the Whole Barrel

- EERE successfully demonstrated cost competitive cellulosic fuel in an industrial setting in 2012
- Improving energy security requires biofuel compatibilities with gasoline, diesel, jet fuel, heavy distillates, and other bio-based products
- Biofuels are a domestic product that can be produced regionally depending on local resources



BETO is developing many products that can be made from petroleum



What is BETO and what do we do?



Planning
 Systems-Level Analysis
 Performance Validation and Assessment
 MYPP
 Peer Review
 Merit Review
 Quarterly Portfolio Review

- WITPP Peer Review Wient Review Quarterly Portfolio Review
 - Competitive
 Non-competitive
 Lab Capabilities Matrix

Research, Development, Demonstration, & Market Transformation

Feedstock Supply & Logistics R&D

- Terrestrial
- Algae
- Product

Logistics Preprocessing

Conversion R&D

- Biochemical
- Thermochemical
- Deconstruction
- Biointermediate
- Upgrading



Demonstration

- & Market Transformation
 - Integrated Biorefineries
- Biofuels
 Distribution
 Infrastructure



Sustainability

- Sustainability Analysis
- Sustainable
 System
 Design



Cross Cutting

Strategic Analysis

- Technology and Resource Assessment
- Market and Impact Analysis
- Model Development & Data compilation



Strategic Communications

- New Communications
 Vehicles & Outlets
- Awareness and Support of Office
- Benefits of



Bioenergy/Bioproducts



Bioproducts: From Niche to Necessity

- Bioproducts :
 - Can replace petroleum-based chemicals and products
 - Provide much **higher margins**, relative to transportation fuels
 - Can be early adopter markets
- Fuels represent 76% of petroleum consumption and \$935B in market value
- Chemicals/products represent only 17% of petroleum consumption but \$812B in market value



Bomgardner Chemical & Engineering News. 92 (43) 10-14. Oct 27, 2014

Bioproducts can enhance the economics of biofuel production