Demonstration and Deployment Workshop

Jonathan Male
Director, Bioenergy Technologies Office
Outline

I. Overview
II. Innovation versus Invention
III. Budget Overview and Funding Opportunities
IV. Aviation Biofuels and Defense Production Act
V. Upcoming BETO Workshops and Events
VI. The Billion Ton Bioeconomy
The Challenge

• More than 13 million barrels of fuel are required every day to fuel the U.S. transportation sector\(^1\)
  o Ethanol is blended up to 10% in current gasoline
• Approximately 10% of U.S. crude oil imports are used to make chemicals and products such as plastics for industrial and consumer goods
  o Biomass derived chemicals make up 4% of current chemical sales
• Less than 2% of the oil consumed in the United States is used for power generation
  o Biopower electricity generation currently accounts for 1.4% of all electricity generated in the United States.

The Potential

• Biomass is a leading renewable resource with the potential to provide drop-in replacements for the 11 million barrels/day of petroleum fuels consumed in 245 million existing light duty and heavy duty vehicles on the road and specifically for air transportation needs (an additional 1 million barrels/day) utilizing existing infrastructure.
• The United States could produce more than 1 billion tons of sustainable biomass resources that can provide fuel for cars, trucks, and jets; make chemicals; and produce power to supply the grid.
• By 2030, there is the potential to develop terrestrial biomass resource to displace 30% of U.S. current petroleum usage. This does NOT take into account algae.
• Produce advanced bioenergy while maintaining food/feed/fiber production, maintaining ecosystem services, and reducing GHG emissions by at least 50% compared to the fossil fuel it displaces.
Bioenergy Technologies Office

Mission

Develop and transform our renewable biomass resources into commercially viable, high-performance biofuels, bioproducts, and biopower through targeted research, development, demonstration, and deployment supported through public and private partnerships.

Strategic Goal

Develop commercially viable biomass utilization technologies to enable the sustainable, nationwide production of biofuels that are compatible with today’s transportation infrastructure and can displace a share of petroleum-derived fuels to reduce U.S. dependence on oil and encourage the creation of a new domestic bioenergy industry.

Performance Goals

• Through RD&D, make cellulosic biofuels competitive with petroleum-based fuels at a modeled cost for mature technology of $3 per gallon of gasoline equivalent (GGE) ($2011) based on EIA projected wholesale prices in 2017.
• Help create an environment conducive to maximizing the production and use of biofuels by 2022.
Bioenergy Supply Chain

**Objective:** Through targeted RD&D, enable sustainable, nationwide production of advanced biofuels that will displace a share of petroleum-derived fuels, mitigate climate change, create American jobs, and increase U.S. energy security.

**Research, Development, and Demonstration at Increasing Scale**

- **Feedstock Supply**
  Develop sustainable and affordable feedstock supply and efficient logistics systems.

- **Conversion R&D**
  Develop commercially viable technologies for converting feedstocks into liquid transportation fuels and products.

- **Demonstration at Increasing Scale**
  Validate integrated technologies at cost-shared pilot, demonstration, and pioneer scale facilities.

**Cross Cutting**

- **Sustainability**
  Promote the positive economic, social, and environmental effects of bioenergy.

- **Strategic Analysis**
  Conduct market, policy, environmental, and other analyses to inform planning and decisions.
Assistant Secretary David Danielson’s Five Questions

- **HIGH IMPACT**: Is this a high impact problem?
- **ADDITIONALITY**: Will the EERE funding make a large difference relative to what the private sector (or other funding entities) is already doing?
- **OPENNESS**: Have we made sure to focus on the broad problem we are trying to solve and be open to new ideas, new approaches, and new performers?
- **ENDURING U.S. ECONOMIC BENEFIT**: How will this EERE funding result in enduring economic benefit to the United States?
- **PROPER ROLE FOR GOVERNMENT**: Why is what we are doing a proper high impact role of government versus something best left to the private sector to address on its own?

**INNOVATION**

-- Innovation is central to each question.
Innovation Versus Invention

• Innovation is the improvement of a product or process (often in combination) which creates meaningful social/economic impact
  “The successful translation of ‘new ideas into tangible societal impact.’”
  - USC Stevens Institute for Innovation

• Innovation often involves:
  o Significant advances along an entire value chain
  o Market demand and public acceptance
  o Correct timing – confluence of historical factors/trends
  o Cross-cutting, interdisciplinary inputs
  o Longer term and significant impacts on economics and culture

• Invention is the starting point for innovation
Innovation is Challenging and Involves Risks

De-risking of technologies is central to R&D into and through demonstration, addressing greater integration and scale:

- BETO is focusing on advancing more technologies, including renewable gasoline, diesel, and jet fuels
- Technical, construction, operational and financial/market risks

Biomass Key Challenges
- Reliable supply
- Consistent quality
- Affordable delivery

Pretreatment Key Challenges
- Biomass feeding
- Biomass sizing and moisture
- Solids handling
- Construction materials

Conversion Key Challenges
- Products yields
- Construction materials
- Catalysts
- Fermentation organisms

Product Key Challenges
- Separations
- Catalytic upgrading
- Recycle loops
### Multi-Decade Endeavor

**Corn Ethanol**

We did not get there overnight

- >11 years to reach 1 billion gallons/year
- +10 years to exceed 2 billion gallons/year
- Latest decade
  - From 2 billion gallons/year to nearly 14 billion gallons/year

**Source:** Renewable Fuels Association: [http://ethanolrfa.org/pages/statistics](http://ethanolrfa.org/pages/statistics)
Scales of Action

**Cellular/Molecular**
- Biochemical, molecular biology, catalytic domains, metal surfaces
- Enzymes
- Ethanologens
- Syngas cleanup
- Pyoil R&D
- Advanced biofuels
- Targeted R&D
- Catalyst Development
- Algal systems

**Reactor Size**
- Biochemical engineering, reactor engineering, pilot plants
- Process Demonstration Systems
  - NREL BC and TC PDUs
  - PNNL TC
  - ANL Separative Bioreactor
  - Algae Demonstration facilities

**Processes**
- demonstration plants, precommercial and commercial plants
- Process engineering, demonstration plants, precommercial and commercial plants
- Fully integrated demonstration or pilot plants (possess integrated feedstock supply & interface, conversion, product recovery and delivery systems)
- Commercial 932 operations and 10% scale Demonstrations (Seven)
- Systems Analysis

**Integration R&D & Analysis**
- Commercial - ethanologen, enzyme, gas clean up, feedstock storage and processing systems
- Pilot Plants - 12 from 2009 ARRA, Innovative Pilots for FY2013 (4)
RD&D Pipeline Evolution of Technology

Bioenergy Technologies Office – Early Stage R&D
Proof of concept of scientific principles, concepts or technologies
Interact with: ARPA-E, SBIR, BRCs (SC), EFRC (SC), Seed Projects

Bioenergy Technologies Office – Feedstocks Logistics & Conversion Program
Development of industrially relevant or applicable technologies

Bioenergy Technologies Office – D & D Program
Demonstrate and Deploy technologies impacting EERE goals and objectives
Interact with: BETO D&D Program & DOE Loan Programs (supporting role)

Interagency Interactions:
- USDA
- Biomass R&D Board
- Feedstocks
- DOD
- NSF

Example: Interface Fuel Cells
Commercial Partnerships

Synergism occurs as interactions increase – Redefine R&D
Outcomes help redefine R&D

Highest risk/broad reward – TRL 1-3
Risk/reward favorable for investment – TRL 7-9
FY12 Key Accomplishment: Cellulosic Ethanol Validations

In September 2012, scientists at DOE’s National Laboratories successfully demonstrated feedstock and conversion processes that reduced the cost of production of cellulosic ethanol

- ~90% reduction in enzyme cost through development of new enzymes for biochemical processing ($3.45/gal to $0.36/gal)
- New microbes that can use more sugars (glucose, xylose, arabinose) - from ~50% to >95%
- Improved methane conversion in thermochemical processes - from 20% to 80%

### Feedstock

- **Biochemical Conversion (Deconstruction and Fermentation)**
  - 2001 = $6.02/gal
  - 2012 = $0.81/gal

### Ethanol

- 2001 = $1.90/gal
- 2012 = $0.51/gal

### Feedstock

- **Thermochemical Conversion (Gasification and Fuels Synthesis)**
  - 2007 = $3.38/gal
  - 2012 = $1.32/gal

### Ethanol

- 2007 = -$0.03/gal
- 2012 = $0.00/gal

**Costs**

- 2001 = $9.17
- 2012 = $2.15
- 2007 = $4.75
- 2012 = $2.05
Greater focus is needed on RD&D for a range of technologies to displace the *entire* barrel of petroleum crude

- U.S. spends about $1B each day on crude oil imports*
- Only about 40% of a barrel of crude oil is used to produce petroleum gasoline
- Biofuels can only displace the portion of the barrel that is made into gasoline.
- Reducing our dependence on oil also requires replacing diesel, jet fuel, heavy distillates, and a range of other chemicals and products that are currently derived from crude oil

*A 42-gallon (U.S.) barrel of crude oil yields about 45 gallons of petroleum products.*

*Source: Energy Information Administration (2011)*
# Bioenergy Technologies Office Budget History

<table>
<thead>
<tr>
<th>Program Area</th>
<th>FY 2012 Enacted</th>
<th>FY 2013 Final CR</th>
<th>FY 2014 OMB Request</th>
<th>FY 2014 Congressional Enacted</th>
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<td>40,500</td>
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<td>76,809</td>
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<td>Integrated Biorefineries</td>
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<td>78,000</td>
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<td>Analysis &amp; Sustainability</td>
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<td>15,000</td>
<td>13,500</td>
<td>12,154</td>
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<td>Biopower/Cookstoves</td>
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<td>4,253</td>
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<td>2,000</td>
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<td>NREL Site-Wide Facility Support</td>
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<td>--</td>
<td>5,000</td>
<td>5,000</td>
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<td><strong>Total, Bioenergy Technologies</strong></td>
<td><strong>199,276</strong></td>
<td><strong>188,430</strong></td>
<td><strong>282,000</strong></td>
<td><strong>232,429</strong></td>
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*In thousands of dollars*
FY13 Feedstock Accomplishments

Sun Grant Regional Feedstock Partnership
• Network of land-grant universities working in partnership with DOE, industry, national labs, and USDA to establish field trials across the country to determine biomass productivity baselines of energy crops.
• Partnership includes over 100 feedstock field trials focused on agricultural residues and energy crops.
• A series of meetings were held in 2013-2014 to map crop productivity and contribute data to Oak Ridge National Laboratory’s Bioenergy Knowledge Discovery Framework (KDF).

Advanced Logistical Systems and Harvesting Technologies
• AGCO received an award in 2009 to demonstrate an efficient harvesting and transport system for corn stover and other herbaceous feedstocks
• Partners included Stinger, Inc., Poet, Abengoa, Terrebon, as well as National Laboratory and university partners.
• As a result of this project, several technologies were developed, including:
  o Single pass combo Combine-Baler
  o High MOG (Material Other than Grain) Combine.
  o Enhanced Density Large Square Baler
FY14 Funding Opportunity Announcements (FOA)

Renewable Carbon Fiber – Released on February 3rd

• This FOA seeks to develop a cost competitive pathway to produce high performance carbon fiber for vehicle lightweighting from renewable non-food biomass.
• The objective of the FOA is to identify and develop a cost-competitive technology pathway to high performance carbon fiber using biomass as a starting raw feedstock and biomass derived acrylonitrile (bio-ACN) as a target product.
• The goal is to produce bio-ACN at a modeled cost of $1.00/lb to enable the overall manufacturing of carbon fiber at $5.00/lb by 2020.

Submission Deadlines:
• Concept Paper Submission Deadline: 3/3/2014 5:00 PM ET
• Full Application Submission Deadline: 4/11/2014 5:00 PM ET

Full FOA information is available on the EERE Exchange: https://eere-exchange.energy.gov/#Foal9c2b53f7-d61a-45a1-b322-20df23a47d0b
Bioenergy Technologies Incubator – Released on February 25th

- BETO issued a FOA for an Incubator Program to support accelerator technologies not currently included in a significant way within BETO’s portfolio.
- The FOA will be “open” to any and all impactful ideas which significantly advance the mission of BETO.
- The total amount of funding for the FOA is $10 million. The estimated period of performance will be approximately 12-24 months, with an award size from $0.5 million to $2.0 million, with 20% cost-share.
- Informational Webinar will be Monday, March 3, 2014 at 1:00 p.m. - 3:00 p.m. EST

Submission Deadlines:
- Concept Paper Submission Deadline: 3/31/2014 5:00 PM ET
- Full Application Submission Deadline: 5/23/2014 5:00 PM ET

Full FOA information is available on the EERE Exchange: https://eereexchange.energy.gov/Default.aspx?Search=DE-FOA-0000974&SearchType=#FoalId28e0ebed-de32-4b3a-97f3-4184df7f5420
In July 2011, the Secretaries of Agriculture, Energy, and Navy signed an Memorandum of Understanding to commit $510 M ($170 M from each agency) to produce hydrocarbon jet and diesel biofuels in the near term. This initiative sought to achieve:

- Multiple, commercial-scale integrated biorefineries
- Cost-competitive biofuel with conventional petroleum (w/o subsidies)
- Domestically produced fuels from non-food feedstocks
- Drop-in, fully compatible, MILSPEC fuels (F-76, JP-5, JP8)
- Help meet the Navy’s demand for 1.26 billion gallons of fuel per year
- Contribute to the Navy’s goal of launching the “Great Green Fleet” in 2016

The first projects selected under DPA are:

<table>
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<tr>
<th>Company</th>
<th>Location</th>
<th>Feedstock</th>
<th>Conversion Pathway</th>
<th>Capacity (MMgpy)</th>
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<tbody>
<tr>
<td>Emerald Biofuels</td>
<td>Gulf Coast</td>
<td>Fats, Oils, and Greases</td>
<td>Hydroprocessed Esters and Fatty Acids (HEFA)</td>
<td>94.0</td>
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<tr>
<td>Natures</td>
<td>South Sioux City, NE</td>
<td>Fats, Oils, and Greases</td>
<td>Hydroprocessed Esters and Fatty Acids (HEFA)</td>
<td>65.8</td>
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<td>Fulcrum Bioenergy</td>
<td>Western United States</td>
<td>Municipal Solid Waste</td>
<td>Gasification – Fischer Tröpsch (FT)</td>
<td>17.0</td>
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<tr>
<td>Red Rock Biofuels</td>
<td>Lakeview, OR</td>
<td>Woody Biomass</td>
<td>Gasification – Fischer Tröpsch (FT)</td>
<td>16.0</td>
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DOE has a $45M appropriation for DPA in FY14
Aviation Biofuels: Accomplishments/Milestones

- Commercial aviation market is currently 20 B gallons/year; CAAFI has set a goal of 1 B gallons/year of alternative jet fuel by 2018.
- BETO staff have played an active role by participating in and providing technical expertise in various high-level aviation activities including:
  - Co-hosted with Federal Aviation Administration (FAA) and CAAFI the Aviation Biofuels Techno-Economic Analysis Workshop, November 2012. (Follow-up workshop being planned for September 2014, BETO goal for preliminary cost targets for jet fuel by December 2014.)
  - Serves on the CAAFI Steering Group and participates in monthly calls.
    - Under Secretary Michael Knotek served as a keynote speaker at CAAFI annual general meeting January 28/29, 2014.
    - DOE and FAA are providing leadership roles in National Alternative Jet Fuels Strategy Roadmap effort (Roadmap expected in December 2014)
  - Supports FAA’s newly established Center of Excellence in alternative jet fuels led by Washington State University/MIT.
    - NREL and PNNL are participants in this Center as are many other organizations and institutions.
  - Increased technical work at National Laboratories to enable achievement of alternative jet fuel goals
Selected Collaborations within EERE

Sustainable Transportation
- Bioenergy Technologies Office
- Fuel Cell Technologies Office (FCTO)
- Vehicle Technologies Office (VTO)

VTO partners with the BETO to support:
- Fuel characterization and combustion testing for biofuels and biofuel blends
- Infrastructure and materials analysis to facilitate biofuel deployment

EERE recently launched the Clean Energy Manufacturing Initiative (CEMI):
- BETO is working with the Advanced Manufacturing Office and VTO on the development of renewable carbon fiber for lightweight vehicles, buildings, and wind energy applications.
Biomass Indirect Liquefaction Workshop
March 20–21, 2014

- The focus of this workshop is to support research and development planning efforts within the thermochemical conversion program. This workshop will discuss and develop ideas and research areas to advance a potential funding opportunity solicitation. This workshop will take place in Golden, Colorado.

Algal Biofuels Spring Strategy Workshop
March 26–27, 2014

- BETO's Algae Program is hosting the spring Algal Biofuels Strategy Workshop, which will focus on the research and development needed to achieve affordable and sustainable algae-based biofuels. The event is a follow-up to the November workshop, and will take place in Charleston, South Carolina.
Upcoming BETO Workshops and Events

Bio-Oil Co-Processing: Expanding the Refinery Supply System
April 3, 2014, New Orleans, Louisiana
• This workshop plans to have renewable technology developers engage with conventional petroleum refiniers to clear up any misconceptions about using biomass-derived oils as additional feedstock. Participants will be engaged in discussions about the potential advantages, disadvantages, and challenges of bio-oil integration in the current U.S. petroleum refinery infrastructure.

Biomass 2014: Growing the Future Bioeconomy
July 29-30, 2014 at Washington Convention Center (tentative)
• BETO plans to host its 7th annual biomass conference to bring together top government officials and members of Congress—with industry leaders and experts from across the bioenergy supply chain—to continue our ongoing dialogue about the critical challenges and key opportunities for the industry.
• This year's conference will focus on the innovative technologies, priority pathways, financing strategies, and public policies needed to grow the bioeconomy of the future.
Our Current Bioeconomy

- Uses about 200 million dry tons of biomass for biofuels, bioproducts, and biopower
- Generates almost 16 GW of electricity from biomass, about 1.5% of total capacity
- Produces over 15 billion gallons of biofuels annually
- Provides about $36 billion in revenue every year and adds another $90 billion to the economy indirectly annually
- Employs about 450,000 people directly
- Reduces CO$_2$-e by almost 145 million tons per year
1. Incubator FOA: https://eere_exchange.energy.gov/Default.aspx?Search=DE-FOA-0000974&SearchType=#FoalId28e0ebed-de32-4b3a-97f3-4184df7f5420

2. Renewable Carbon Fiber FOA https://eere-exchange.energy.gov/#FoalId9c2b53f7-d61a-45a1-b322-20df23a47d0b


Boundary Sketch for Annual Revenue

Basis: Income generated from the revenue streams identified below are taxable

Revenue to Grower / Harvester: Feedstock value prior to pre-processing

Revenue to Feedstock Depot: Feedstock value at the entrance to the conversion plant

Revenue to IBR Facilities: Values of Biofuel and Bioproduct IBR facilities

Revenue to Product Distributors: Product distribution to end use or petroleum refinery

Biomass Production → Feedstock Logistics → Conversion → Distribution → End Use

Direct Revenue from Supply-Chain Operations (Fixed and Variable Operating Costs): Costs for salaries and wages, raw materials, catalysts and chemicals, insurance, replacement capital equipment, facility maintenance, etc. along the supply-chain that directly contributes to economic value.
Renewable Fuel Standard (RFS) in 2014

On November 15th, the EPA issued its proposed 2014 standards for the RFS program.

- DOE’s primary role in EPA’s rule-making process is to ensure that accurate and realistic information is used in setting the regulatory standards
- DOE’s long-term role is to invest in the RDD&D for advanced bioenergy technologies needed to meet the goals of the RFS

<table>
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<tr>
<th>Company/Location</th>
<th>Projected 2014 Vol. (Gal.)</th>
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<tbody>
<tr>
<td>Abengoa, KS*</td>
<td>0-18 M Gal.</td>
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<tr>
<td>DuPont, IA*</td>
<td>0-2 M Gal.</td>
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<tr>
<td>INEOS, FL*</td>
<td>2-5 M Gal.</td>
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<tr>
<td>POET, IA*</td>
<td>0-6 M Gal.</td>
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<tr>
<td>KiOR, MS</td>
<td>0-9 M Gal.</td>
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EPA requested stakeholder comment on proposed 2014 rule-making and is in the process of reviewing comments received.

More information is available at regulations.gov

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<tr>
<th></th>
<th>Vol. used 2013 standards (gal.)</th>
<th>Proposed 2014 vol. req. (gal.)</th>
<th>Req. vol. for 2014 under the CAA (gal.)</th>
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<td>Cellulosic Biofuel</td>
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<td>17 M</td>
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<td>Biomass-based Diesel</td>
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<td>1,280 M</td>
<td>≥ 1,000 M</td>
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<td>Advanced Biofuel</td>
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<td>3,750 M</td>
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<td>Renewable Biofuel</td>
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<td>15,210 M</td>
<td>18,150 M</td>
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*DOE-supported technology