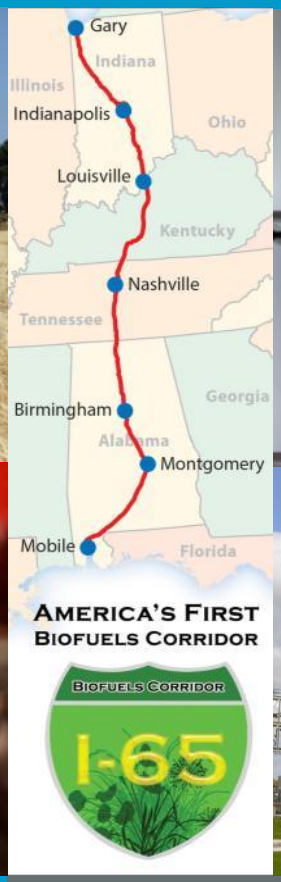
BIOENERGY TECHNOLOGIES OFFICE

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



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 and The Opportunity

The Challenge

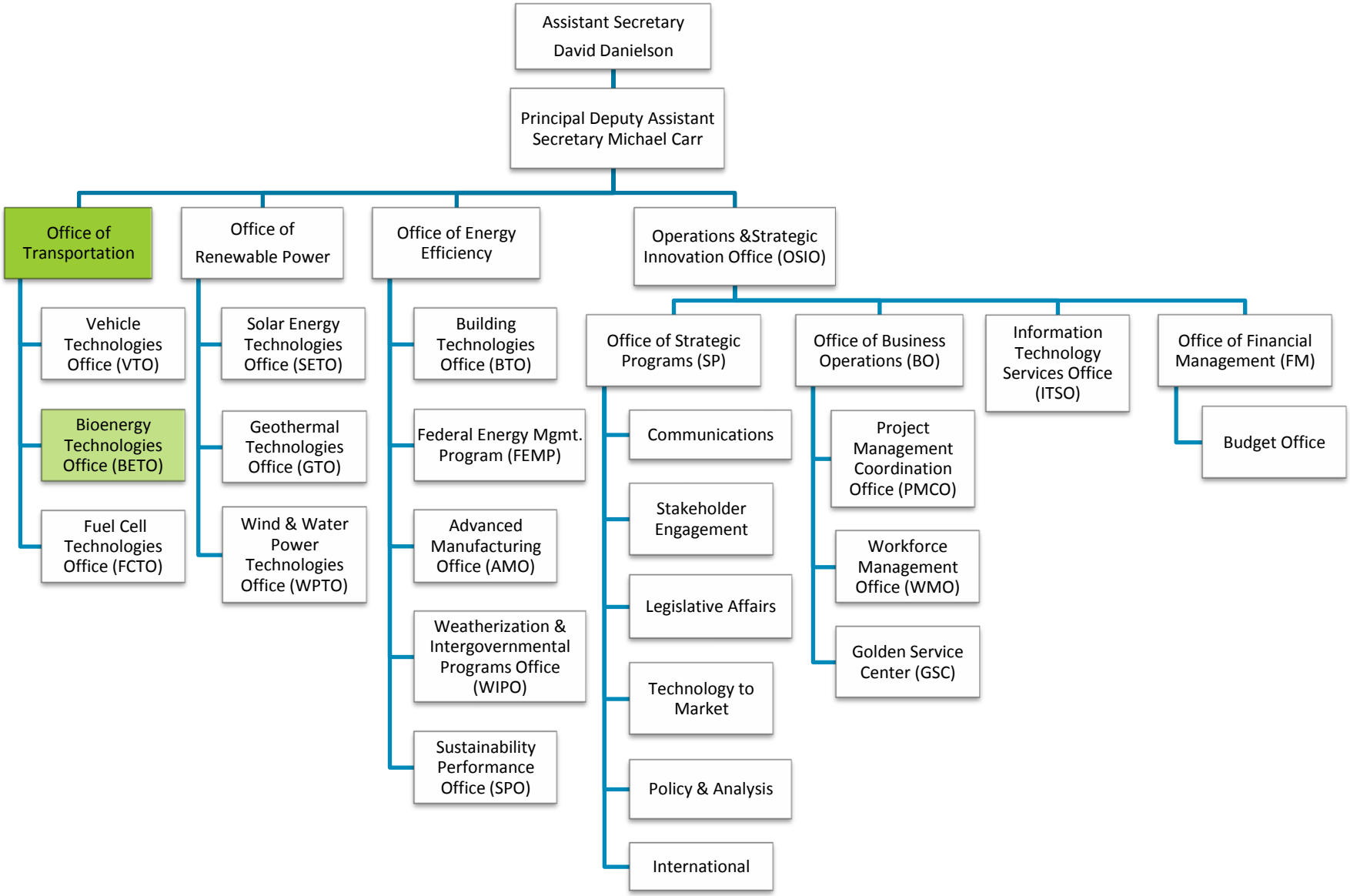
- More than 13 million barrels of fuel are required every day to fuel the U.S. transportation sector[1]
  - Ethanol is blended up to 10% in current gasoline
- Approximately 10% of U.S. crude oil imports are used to make chemicals and products such as plastics for industrial and consumer goods
  - Biomass 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
  - 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.

[1] EIA 2012 Energy Review

EERE Organization Chart



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 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.

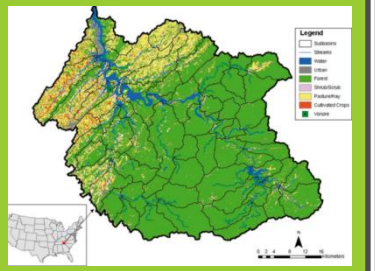
Demonstration at Increasing Scale

Validate integrated technologies at cost-shared pilot, demonstration, and pioneer scale facilities.

Cross Cutting

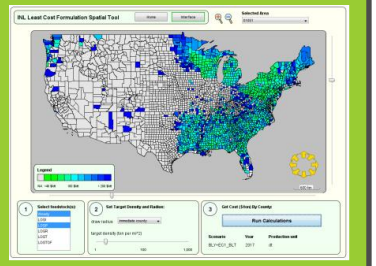
Sustainability

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

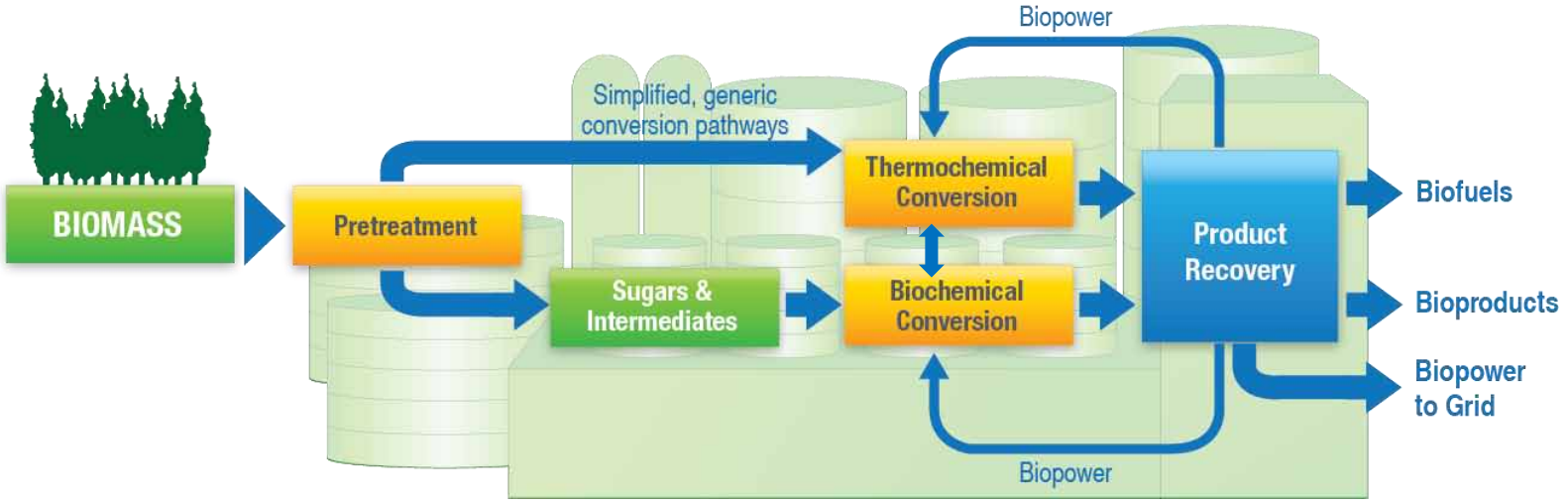
- Innovation often involves:
  - Significant advances along an entire value chain
  - Market demand and public acceptance
  - Correct timing – confluence of historical factors/trends
  - Cross-cutting, interdisciplinary inputs
  - Longer term and significant impacts on economics and culture

- 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

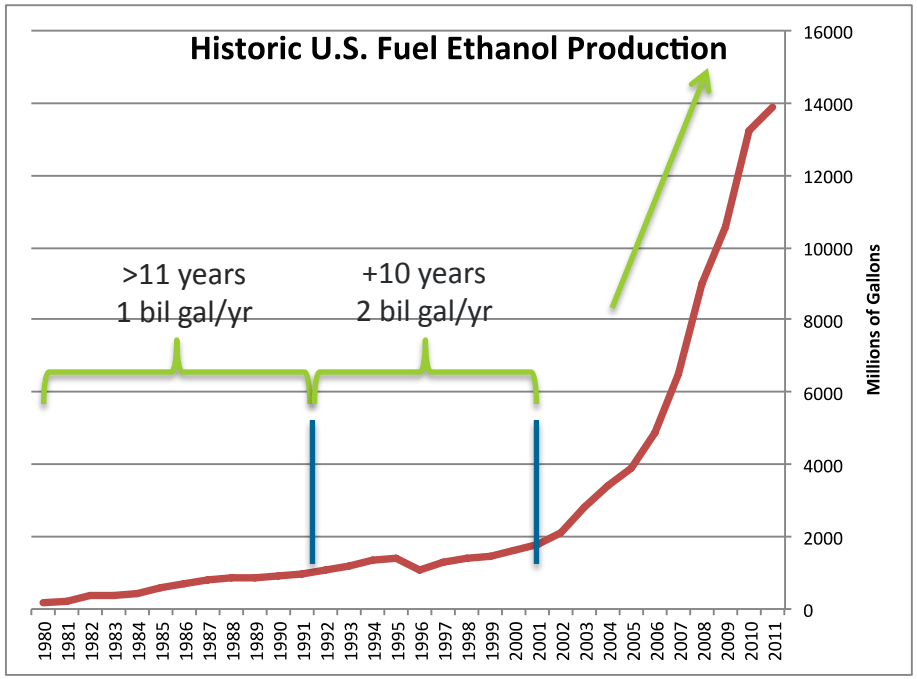


Biomass Key Challenges	Pretreatment Key Challenges	Conversion Key Challenges	Product Key Challenges
•Reliable supply •Consistent quality •Affordable delivery	•Biomass feeding •Biomass sizing and moisture •Solids handling •Construction materials	•Products Yields •Construction materials •Catalysts •Fermentation organisms	•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

Scales of Action

Cellular/Molecular
nanometers

Reactor Size
meters

Processes
acres or hectares

Biochemical, molecular biology, catalytic domains, metal surfaces

Enzymes

Ethanologens

Syngas cleanup

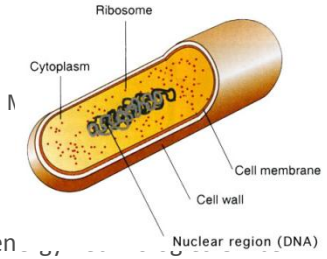
Pyoil R&D

Advanced biofuels

Targeted R&D

Catalyst Development

Algal systems

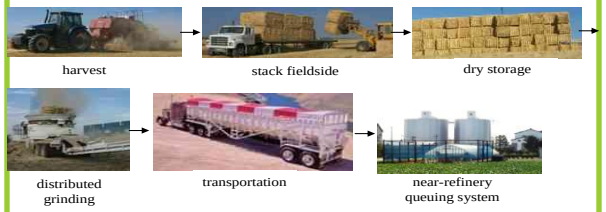


Biochemical engineering, reactor engineering, pilot plants

Process Demonstration Systems

- NREL BC and TC PDUs
- PNNL TC
- ANL Separative Bioreactor
- Algae Demonstration facilities

Feedstock Interfaces



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)

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

RD&D Pipeline Evolution of Technology

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)

Pilot Operations | Integrated Pilots | Demonstrate | Commercial Demos

Example: Interface Fuel Cells

Commercial Partnerships

Bioenergy Technologies Office – Feedstocks Logistics & Conversion Program

Development of industrially relevant or applicable technologies

Concept Designed | Concept Engineered | Engineering Development | Proof at scale

Early Stage R&D

Proof of concept of scientific principles, concepts or technologies

Interact with:
ARPA-E, SBIR
BRCs (SC), EFRC (SC)
Seed Projects

Interagency Interactions:

-USDA
-Biomass R&D Board
-Feedstocks
- DOD
- NSF

Synergism occurs as interactions increase – Outcomes help (re)define R&D

Reactor Size meters

Cellular/Molecular 1 µm

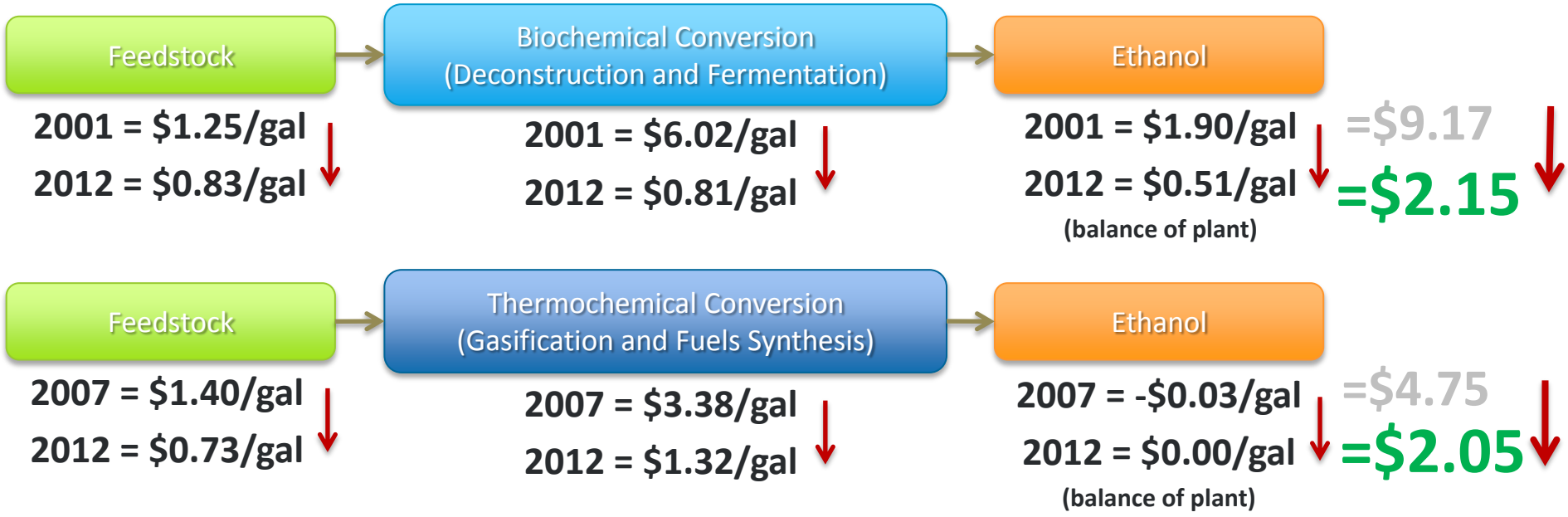
Highest risk/broad reward – TRL 1-3

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

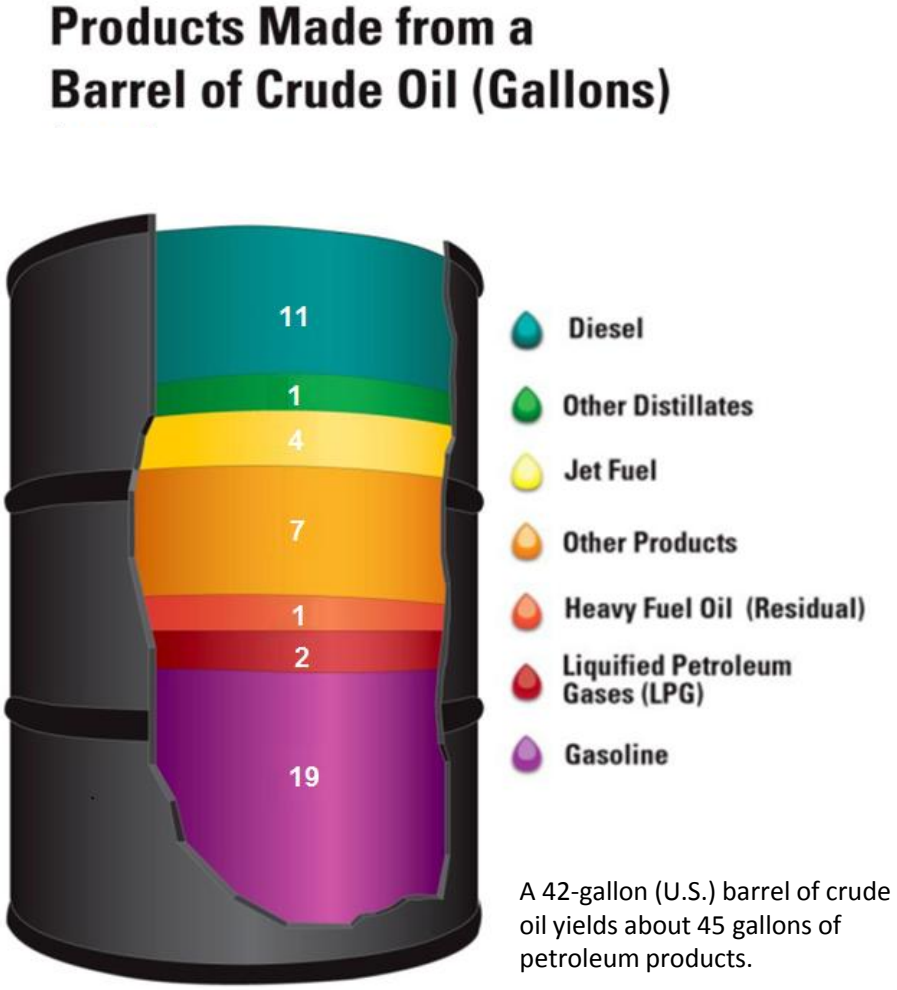
- ~90% reduction in enzyme cost through development of new enzymes for biochemical processing ($3.45/gal to $0.36/gal)
- New microbes that can use more sugars (glucose, xylose, arabinose) - from ~50% to >95%
- Improved methane conversion in thermochemical processes - from 20% to 80%



Replacing the Whole Barrel

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)

*American Petroleum Institute

Bioenergy Technologies Office Budget History

Program Area	FY 2012 Enacted	FY 2013 Final CR	FY 2014 OMB Request	FY 2014 Congressional Enacted
Feedstocks	35,922	48,500	40,500	47,000
Conversion Technologies	105,531	76,809	141,000	101,446
Integrated Biorefineries	42,897	43,868	78,000	64,829
Analysis & Sustainability	9,951	15,000	13,500	12,154
Biopower/Cookstoves	4,975	4,253	4,000	2,000
NREL Site-Wide Facility Support	--	--	5,000	5,000
Total, Bioenergy Technologies	199,276	188,430	282,000	232,429

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:
    - Single pass combo Combine-Baler
    - High MOG (Material Other than Grain) Combine.
    - Enhanced Density Large Square Baler

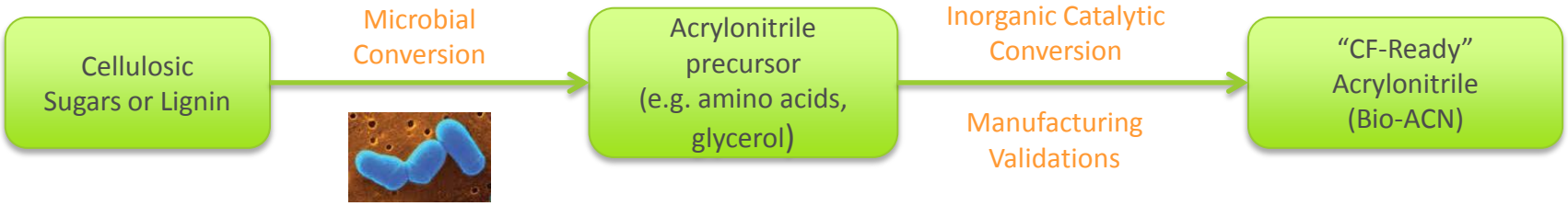
FY14 Funding Opportunity Announcements (FOA)

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/#FoaId9c2b53f7-d61a-45a1-b322-20df23a47d0b

FY14 Funding Opportunity Announcements (FOA)

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://eere exchange.energy.gov/Default.aspx?Search=DE-FOA-0000974&SearchType=#FoaId28e0ebed-de32-4b3a-97f3-4184df7f5420

Defense Production Act (DPA) Initiative

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

DOE has a $45M appropriation for DPA in FY14

The first projects selected under DPA are:

Company	Location	Feedstock	Conversion Pathway	Capacity (MMgpy)
Emerald Biofuels	Gulf Coast	Fats, Oils, and Greases	Hydroprocessed Esters and Fatty Acids (HEFA)	94.0
Natures BioReserve™	South Sioux City, NE	Fats, Oils, and Greases	Hydroprocessed Esters and Fatty Acids (HEFA)	65.8
Fulcrum BIOENERGY	Western United States	Municipal Solid Waste	Gasification – Fischer Tröpsch (FT)	17.0
Red Rock Biofuels	Lakeview, OR	Woody Biomass	Gasification – Fischer Tröpsch (FT)	16.0

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

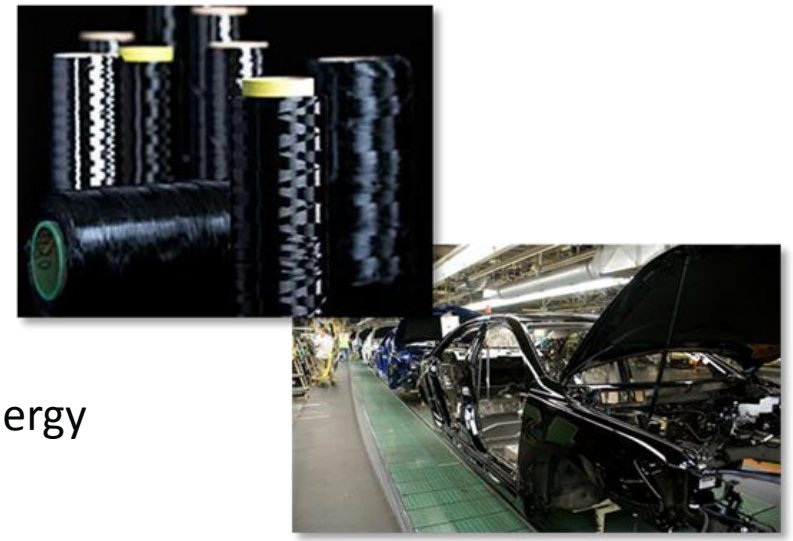
- Bioenergy Technologies Office
- Fuel Cell Technologies Office (FCTO)
- Vehicle Technologies Office (VTO)

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.



Upcoming BETO Workshops and Events

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 refiners 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

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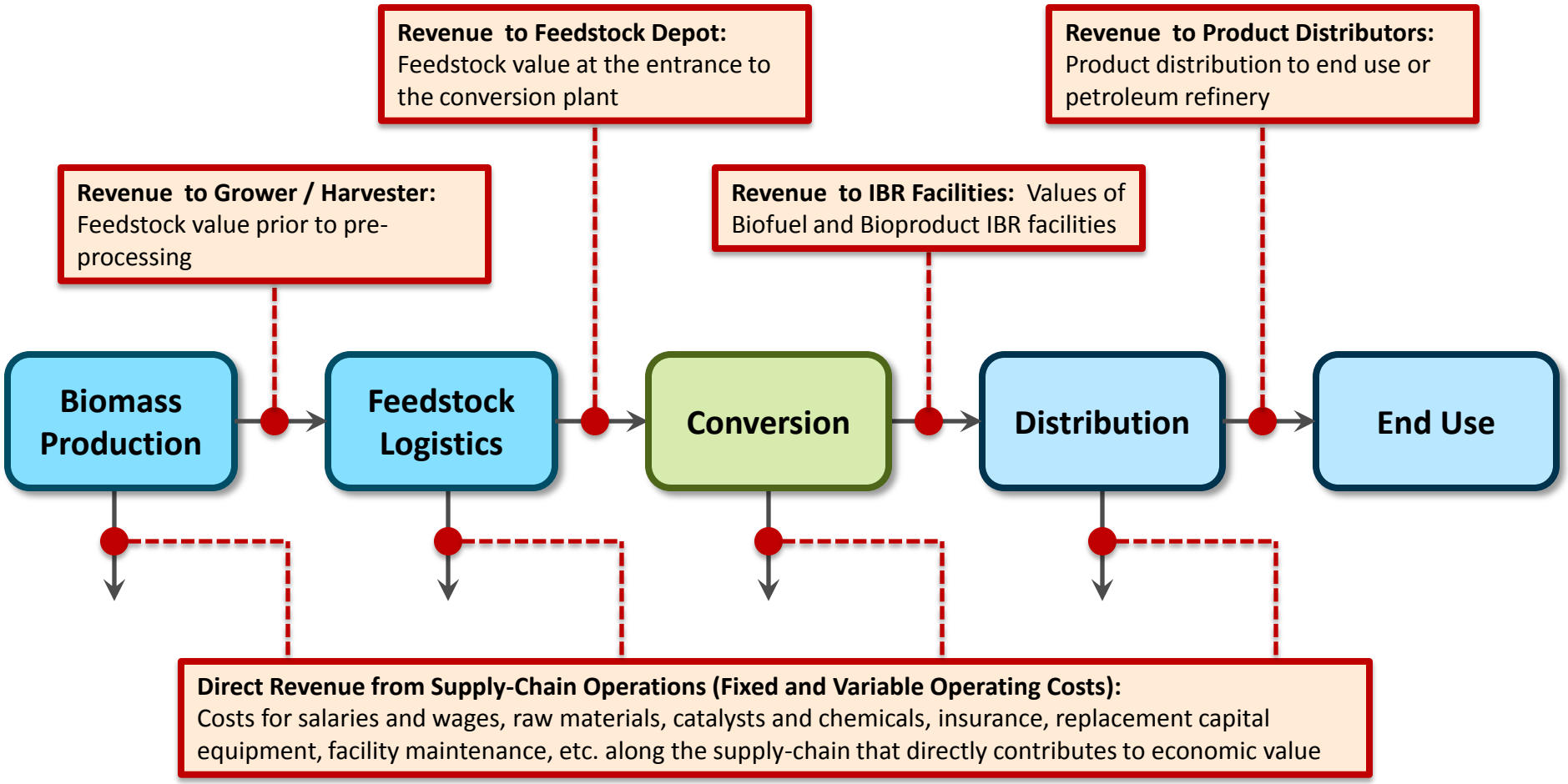
Useful Links

1. Incubator FOA: https://eere exchange.energy.gov/Default.aspx?Search=DE-FOA- 0000974&SearchType=#FoaId28e0ebed-de32-4b3a-97f3-4184df7f5420
2. Renewable Carbon Fiber FOA https://eere-exchange.energy.gov/#FoaId9c2b53f7-d61a-45a1-b322-20df23a47d0b
3. Updated Fast Pyrolysis Design Report: http://www.pnnl.gov/main/publications/external/technical reports/PNNL-23053.pdf
4. BETO News and Announcements http://www1.eere.energy.gov/bioenergy/news.html
5. 2013 Peer Review http://www1.eere.energy.gov/biomass/peer review2013.html
6. Biomass R&D Board http://www.biomassboard.gov/

Appendix

Boundary Sketch for Annual Revenue

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



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

	Vol. used 2013 standards (gal.)	Proposed 2014 vol. req. (gal.)	Req. vol. for 2014 under the CAA (gal.)
Cellulosic Biofuel	6 M	17 M	1,750 M
Biomass-based Diesel	1,280 M	1,280 M	≥ 1,000 M
Advanced Biofuel	2,750 M	2,220 M	3,750 M
Renewable Biofuel	16,550 M	15,210 M	18,150 M

Company/ Location	Projected 2014 Vol. (Gal.)
Abengoa, KS*	0-18 M Gal.
DuPont, IA*	0-2 M Gal.
INEOS, FL*	2-5 M Gal.
POET, IA*	0-6 M Gal.
KiOR, MS	0-9 M Gal.

*DOE-supported technology

- 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