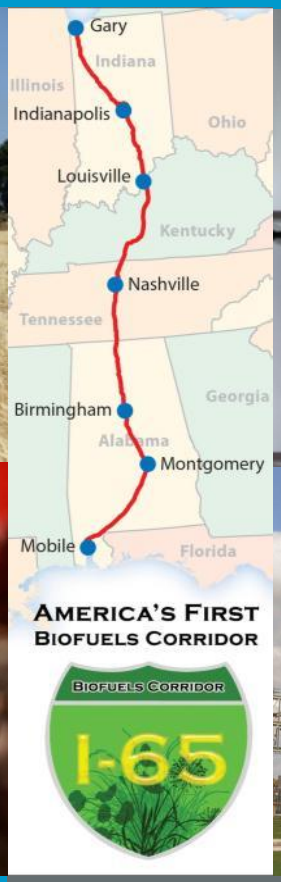
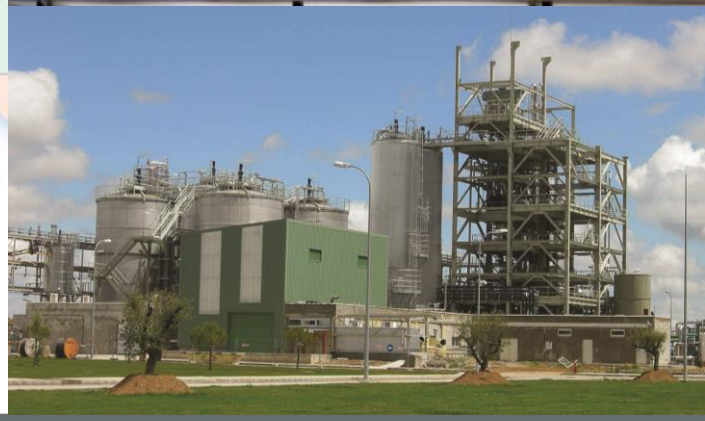
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy





Biomass R&D Technical Advisory Committee (TAC)

March 8, 2016

Jonathan Male

Director

Bioenergy Technologies Office

Contents

Office of Energy Efficiency and Renewable Energy

Sustainable
TRANSPORTATION

Renewable
ELECTRICITY GENERATION

Energy Saving
HOMES, BUILDINGS, & MANUFACTURING

Mission-Critical Support
OPERATIONS

The Challenge and the Opportunity

THE CHALLENGE

- **More than $1 Billion** is spent every three days on U.S. crude oil imports
- Transportation accounts for **2/3^{rds}** of petroleum consumption and **26%** of GHG emissions in the U.S.

THE OPPORTUNITY

- More than **1 Billion tons** of biomass could be sustainably produced in the U.S.
- Biomass could displace up to 30% of U.S. petroleum use by 2030 and reduce annual CO_2e by 400 million tons, or 7% of U.S. energy emissions

America's biomass resources can help mitigate petroleum dependence

Bioenergy Technologies Office

Accelerate commercialization of advanced bioenergy through RD&D supported by public-private partnerships

Promote sustainable, nationwide production of infrastructure-compatible biofuels

Validate at least one pathway for $3/GGE* hydrocarbon biofuel with ≥50% reduction in GHG emissions by 2017

*Mature modeled price at pilot scale.

BETO reduces risks and costs to commercialization through RD&D

BETO's Core Focus Areas

Program Portfolio Management

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

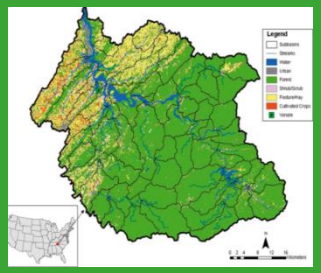
Demonstration & Market Transformation

- Integrated Biorefineries
- Biofuels Distribution Infrastructure

Cross Cutting

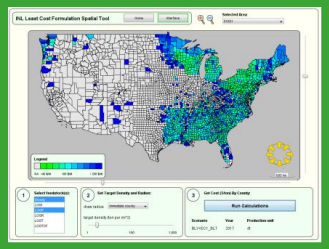
Sustainability

- Sustainability Analysis
- Sustainable System Design



Strategic Analysis

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

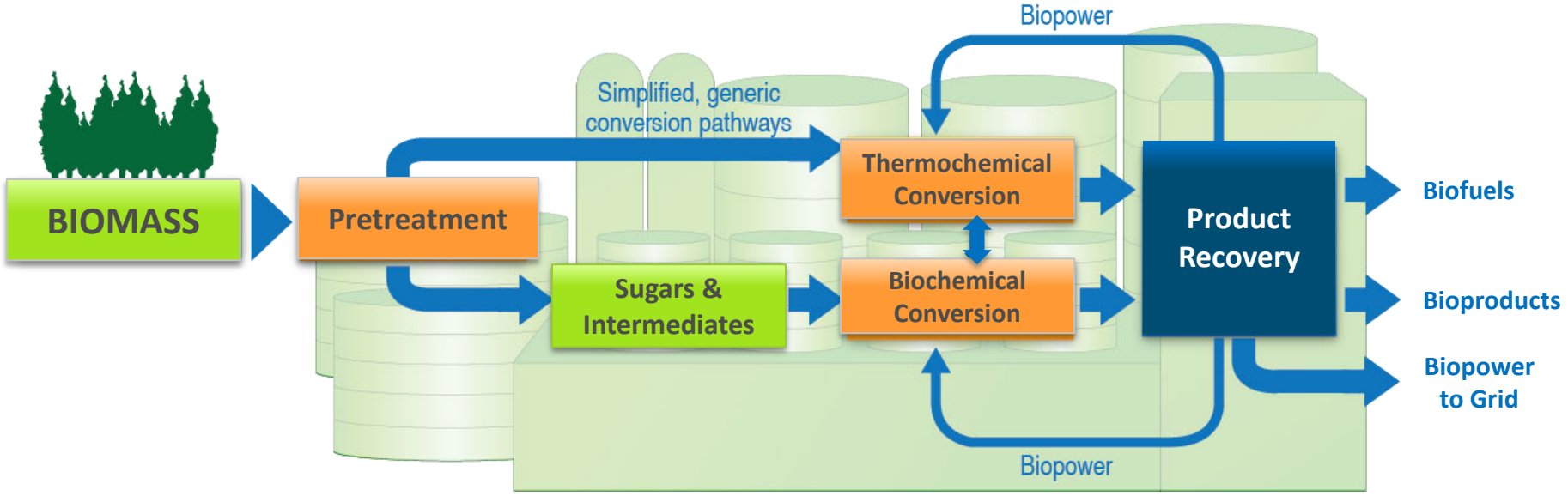


Strategic Communications

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

Key Challenges for Biofuels

- Technical, construction, operational, financial and market risk reduction
- Demonstration through greater process integration and scale



Key Challenges			
Biomass	**Pretreatment**	**Conversion**	**Product**
• Reliable supply • Consistent quality • Affordable delivery	• Biomass feeding, sizing and moisture • Solids handling • Construction materials	• Products Yields • Construction materials • Catalysts • Fermentation organisms	• Separations • Catalytic upgrading • Recycle loops

DOE works to address risks and reduce costs across the supply chain

Administration's Bioenergy Goals

National Energy Goals & Climate Action Plan

Net Oil Imports

50% by 2020

GHG Emissions

26-28% by 2025

>80% by 2050

BETO Performance Goal: Hydrocarbon Biofuel Production

$3/GGE by 2017

50% GHG reduction vs. petroleum fuel

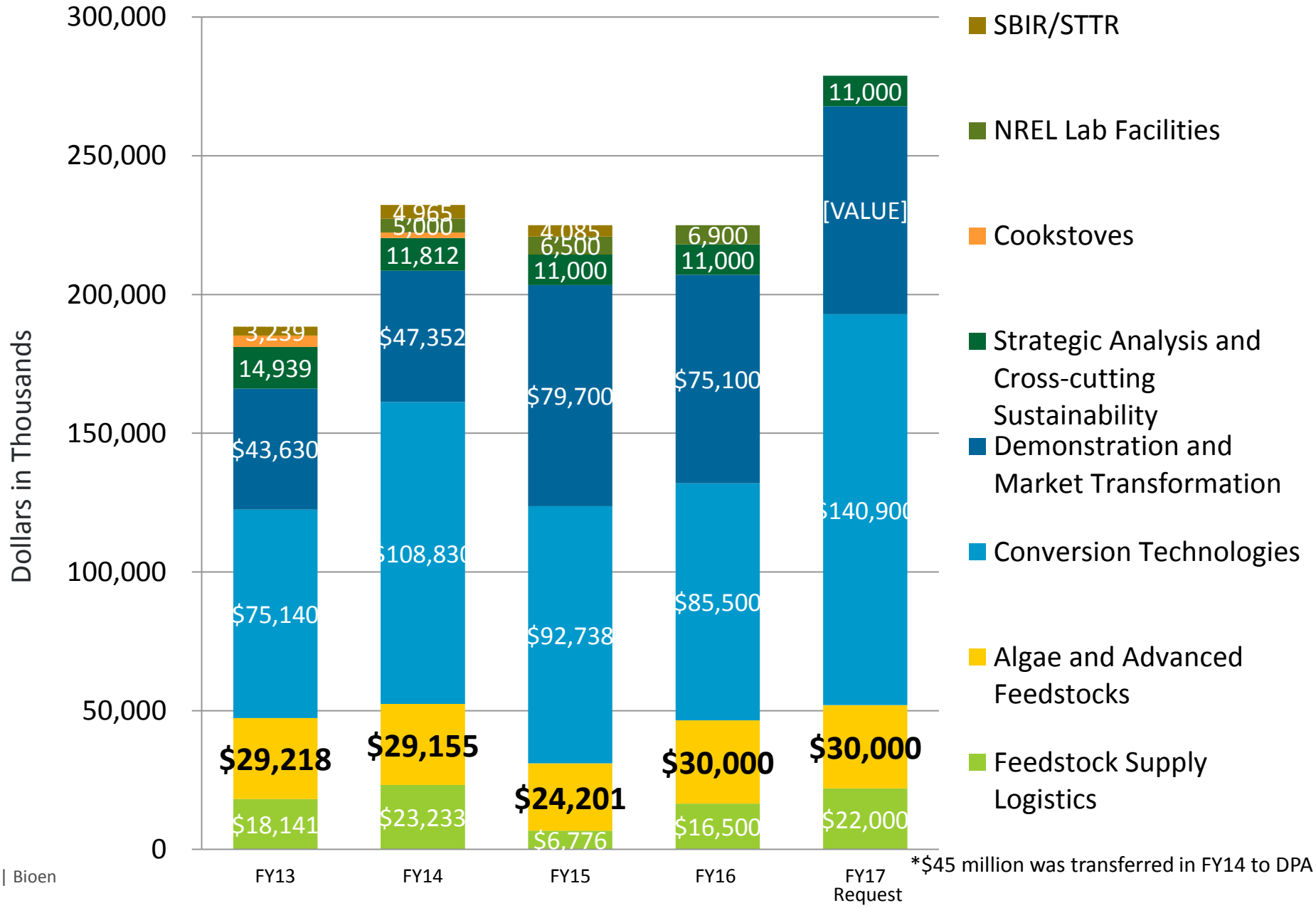
BETO Performance Goal: Hydrocarbon Pathway Validation

Two Additional Pathways by 2022

Pilot or Demo Scale (>1 ton/day)

BETO's goals support the Presidential Initiatives on Energy

Bioenergy Technologies Office Funding



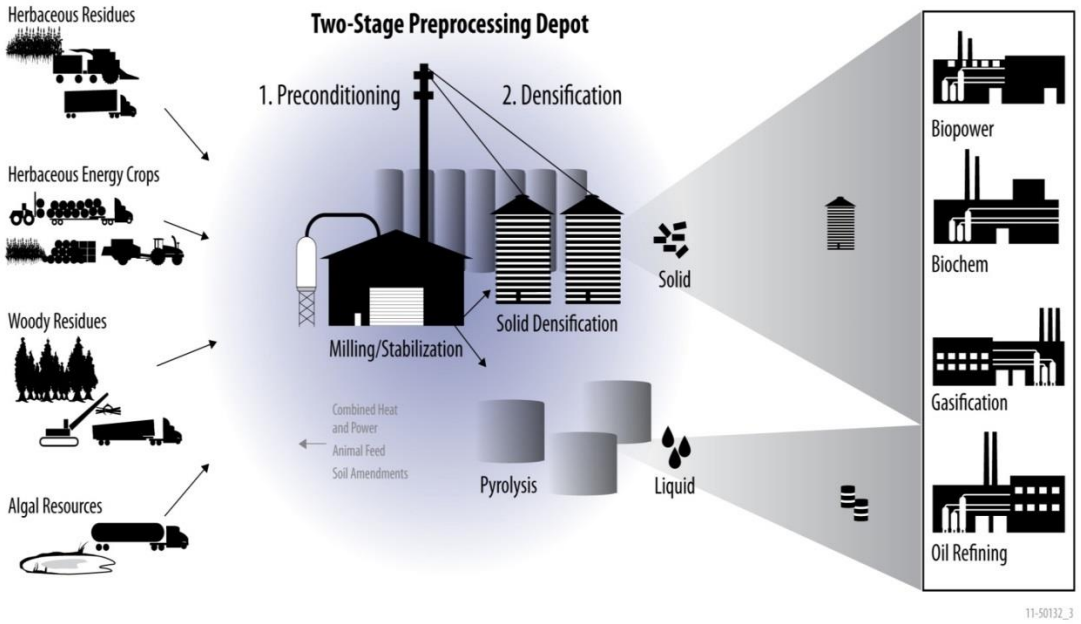
*$45 million was transferred in FY14 to DPA

Program Achievements in FY15

- **Feedstocks Supply and Logistics**
  - Idaho National Laboratory successfully completed two State of Technology (SOT) reports on herbaceous and woody energy crops. The SOT reports highlight progress towards meeting the 2017 goal of validating a supply and logistics system that is capable of delivering feedstocks to the conversion reactor throat at $80/dry ton.
- **Advanced Algal Systems**
  - Establishment of CalPoly's Delhi Field Site (9,000 L system with continuous automated process controls and harvest equipment at Delhi, CA WWT facility for the ABY project).
- **Conversion Technologies**
  - Reduce the modeled conversion cost contribution from $4.09/gge to $3.70/gge via fast pyrolysis for converting biomass to a hydrocarbon fuel blendstock in a mature commercial-scale plant.
  - Reduce modeled mature biochemical conversion cost from $9/GGE to $6.40/GGE of combined hydrocarbon fuel on a pathway to a $3.17/gge conversion cost demonstrated in 2017 at the bench and pilot scale by improving co-product organisms, primary fermentation organisms for fatty acid production and reducing operating costs.
- **Demonstration and Market Transformation**
  - The Haldor Topsoe, Inc. initiative in Des Plaines, IL focusses on the thermochemical conversion of wood waste and woody biomass to gasoline with an expected production of 345,000 gal/year.
  - Accomplishments thus far include acceptable ranges for gasoline blendstock, emission levels similar to gasoline
- **Analysis and Sustainability**
  - ANL released WATER 3.0 to enable in-depth analysis of water consumption for multiple biofuels pathways. NREL assessed applicable federal air quality regulations and estimates of seven criteria air pollutant emissions for the fast pyrolysis pathway.

Feedstock Logistics Activities

Objective: Transform raw biomass into high-density, stable, commodity feedstocks.



Priorities for next 5-10 years

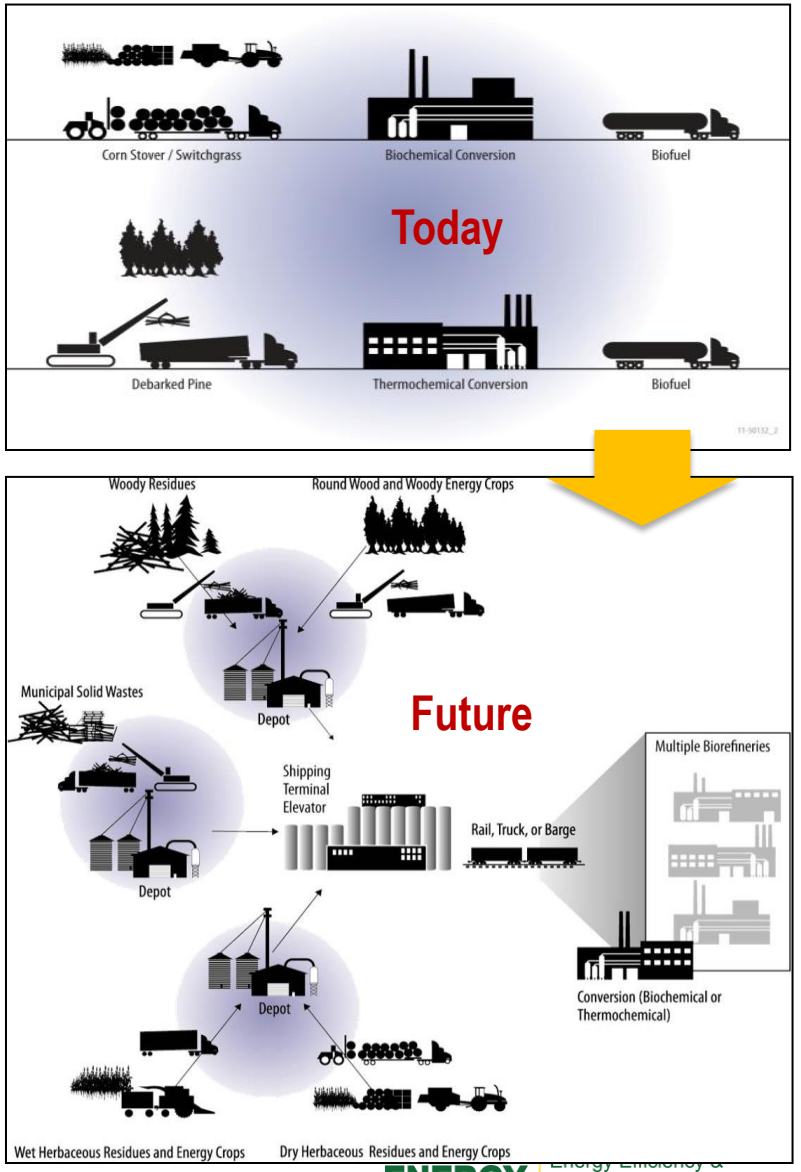
- Identify and validate markets in which logistics can establish a competitive position vs. the current supply and demand.
- Enhance the performance of the logistics equipment to efficiently handle different types of regional biomass.
- Test and validate at-scale.
- Enable national biomass utilization.

Advanced logistics work for FY16

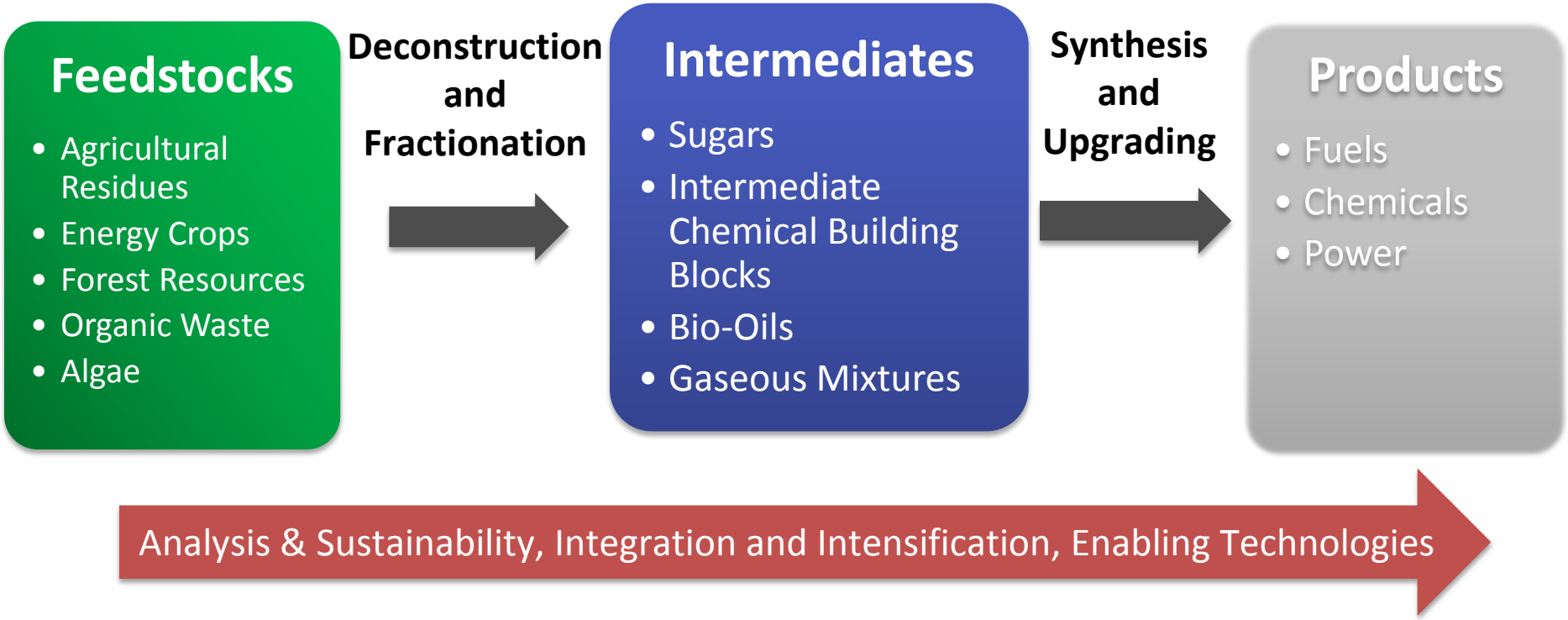
- Actively manage feedstock variability and supply uncertainty: downselect to working blends meeting cost, quality, and convertibility targets.
- Scale-up: Advanced logistics projects; PDU.

What is the Advanced Feedstock Supply System (AFSS)?

- The AFSS refers to a system or set of processes sized at the characteristic scale of biomass (i.e., small, modular and distributed) that transforms biomass resources into merchandisable, tradable, and aggregatable intermediates.
  - Depots must become an economically independent business unit regardless of vertically integrated association with the biorefinery in order to create market pull.
- The AFSS concept provides for a "transitional" strategy of value-added preprocessing such as blending, formulation, torrefaction, and other approaches to produce intermediate products that serve biorefining and other markets.



Overview of Conversion Research & Development



Strategic Goal: Develop commercially viable technologies for converting biomass feedstocks via biological and chemical routes into energy-dense, fungible, finished liquid transportation fuels such as renewable gasoline, diesel, and jet fuel, as well as bioproducts or chemical intermediates and biopower.

BETO R&D and Enabling the Bioeconomy

- As BETO increasingly focuses on hydrocarbon fuels, it is examining strategies that capitalize on revenue from bioproducts as part of cost-competitive biofuel production.
- BETO R&D includes research into pathways from feedstocks to biofuels that also generate value added products to help meet cost targets
- Industry recipients of competitive awards including Genomatica and Natureworks have also made advances in the development of bio-based products
- Targeted bioproducts may fall into the following categories
  - Molecular replacements for petroleum derived chemicals
  - Performance replacements for petroleum derived chemicals
- Infancy stage – play to the strength of the oxygenated polymers in biomass
  - Lignin and waste streams to value added products (X2 the cost of biofuels on a mass basis)

Bioproducts: From Niche to Necessity

- Bioproducts can replace petroleum-based chemicals and products
- Provide much higher value-added margins, relative to transportation fuels
- Bioproducts could be early adopter markets
- Chemicals/products represent **16%** of petroleum consumption and **$812B** in market value
- Fuels represent **76%** of petroleum consumption, and **$935B** in market value


Hydroxypropionic acid


Ethylene glycol


1,3 Propanediol


Hexamethylenediamine


Succinic acid


1,4-Butanediol


Butadiene

Bioproducts can enhance the economics of biofuel production

DOE-Supported Cellulosic Ethanol Biorefineries

DuPont

- Nevada, Iowa
- Opened October 2015
- 30 MGY of cellulosic ethanol from corn stover

POET-DSM Project Liberty

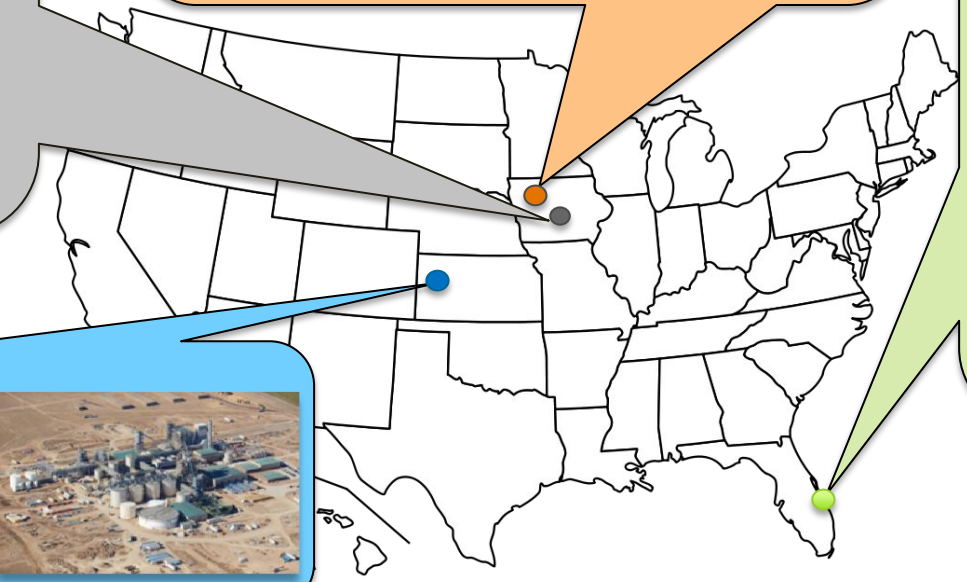
- Emmetsburg, Iowa
- Opened September 2014
- 25 MGY of cellulosic ethanol from corn stover

INEOS

- Vero Beach, Florida
- Opened July 2013
- 8 MGY of cellulosic ethanol from vegetative waste

Abengoa

- Hugoton, Kansas
- Opened October 2014
- 25 MGY of cellulosic Ethanol from corn stover



1993	2003	2007	2009	2013	2014	2015
INEOS wins DOE-SBIR Grant	Abengoa builds DOE-supported pilot plant in York, Nebraska	Abengoa and POET win awards funded under EPACT05	INEOS wins ARRA Grant	INEOS Opens	POET and Abengoa Open	***DuPont Opens***

After decades of DOE partnerships, 4 commercial scale biorefineries have begun production

Defense Production Act (DPA) Initiative

In September 2014, 3 projects were selected under the DPA Initiative to build commercial biorefineries to produce:

- Drop-in fuels for military applications
- Domestic fuels from non-food biomass feedstocks
- Cost-competitive biofuels (without subsidies)

Company	Location	Feedstock	Capacity	Groundbreaking	Off-Take Agreements
Emerald Biofuels	Gulf Coast	Fats and Greases	82 MM g/y	TBA	TBD
Fulcrum Bioenergy	McCarran, NV	MSW	10 MM g/y	Summer of 2016	United, Cathay Pacific
Red Rock Biofuels	Lakeview, OR	Woody Biomass	12 MM g/y	TBA	Southwest Airlines

Interagency initiative to produce more than 100 MM g/y of advanced biofuels

BETO FY16 Goals

- Reduce modeled thermochemical conversion cost of a combined gasoline and diesel production ($/gallons of gasoline equivalent).
- Demonstrate at least one pathway capable of achieving the FY2018 target of 2,500 gallons of algal biofuel intermediate per acre (annual average).
- Select up to 10 pilot-scale and 4 demonstration-scale projects for Validation, Design and Due Diligence (Phase 1) under the combined FY16 FOA on Integrated Biorefinery and Waste-to-Energy.
- Defense Production Act (DPA) Advanced Biofuels Initiative - Enable and review construction on 2 of the 3 project selected for Phase II construction.
- Execute first year of co-optimization of fuels-engine effort under Optima banner.

FY 2016 Priority Activities

- **Algae:** Pursue new research in advanced biology and carbon dioxide utilization to address yield, productivity, and integration of downstream logistics at the pre-pilot scale.
- **Conversion:** Select and complete preparation of at least two pathways for validation at integrated bench or pilot scale in FY 2017 of modeled mature $3/gge gasoline/diesel blendstock price and progress toward FY 2022 price goals ($3/gge).
- **Feedstock Supply:** Focus on feedstock supply and logistics technologies to help meet biomass feedstock price targets of $80/Dry Matter Ton in 2017.
- **New Fuels and Vehicle Systems Co-Optima:** Establishes a link early in the R&D cycle of both fuels and engines for a systems-based approach and to create optimized solutions for fuels and engines. Collaboration with Vehicles Technologies.
- **New Investments in the Integrated Production and Scale-Up of Drop-in Hydrocarbon Fuels:** New competitive awards (up to three pilot projects or one demonstration project) to scale-up integrated production systems of drop-in hydrocarbon biofuels to accelerate advanced biofuel manufacturing.
- **DPA:** Support the military-specification jet fuel in collaboration with DoD and USDA through the Defense Production Act.

MEGA-BIO FOA – Bioproducts to Enable Biofuels

- **Goal:** The MEGA BIO FOA will identify research and development (R&D) projects that propose a conversion pathway that may flexibly produce bioproducts and biofuels.
- **Topics:** The FOA selection process will identify projects in two topic areas:
  1. **Early Technology Readiness Level (TRL) (TRL 2–3)** R&D to optimize one unit operation of the proposed conversion pathway.
  2. **Middle Technology Readiness Level (TRL 4–5)** R&D to optimize and integrate multiple unit operations of the proposed conversion pathway
- **Awards:**
  - Total $11.3M
  - 1-10 awards anticipated between $1M - $8M
- **Status:**
  - Announced February 8, 2016
  - Concept Papers due February 26, 2016
  - Full Applications due April 15, 2016

Photo credits NREL and Arizona State University

Algal Biomass Yield Phase 2 FOA

- **Goal:** The ABY Phase 2 FOA will develop technologies that are likely to succeed in producing 3,700 gallons of algal biofuel intermediate (or equivalent dry weight basis) per acre per year (gal/acre/yr) on an annualized average basis under conditions that result in favorable life-cycle greenhouse gas reductions and techno-economic analyses.
- **Topics:** The FOA selection process will identify projects in two topic areas:
  1. **Strain/productivity improvement**
  2. **Improvements in pre-processing technologies (harvesting, dewatering, and extraction and/or equivalent processes)**
  3. **Integration of cultivation with pre-processing technologies**
- **Awards:**
  - Total $15M, 2-6 awards anticipated
- **Status:**
  - Announced January 15, 2016
  - Concept Papers due February 12, 2016
  - Full Applications due March 25, 2016

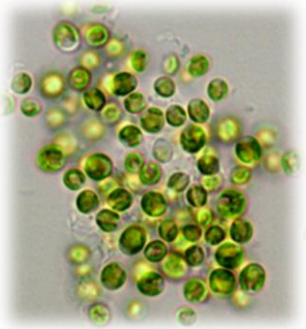


Photo credits NREL and Arizona State University

Co-Optimization of Fuels and Engines

better fuels. better vehicles. sooner.

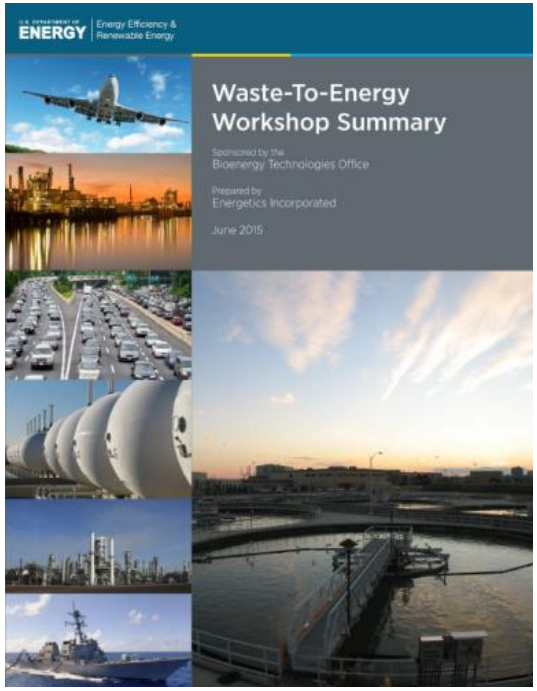
Draws on collaborative expertise of two DOE research offices, nine national laboratories, and numerous industry and academic partners.

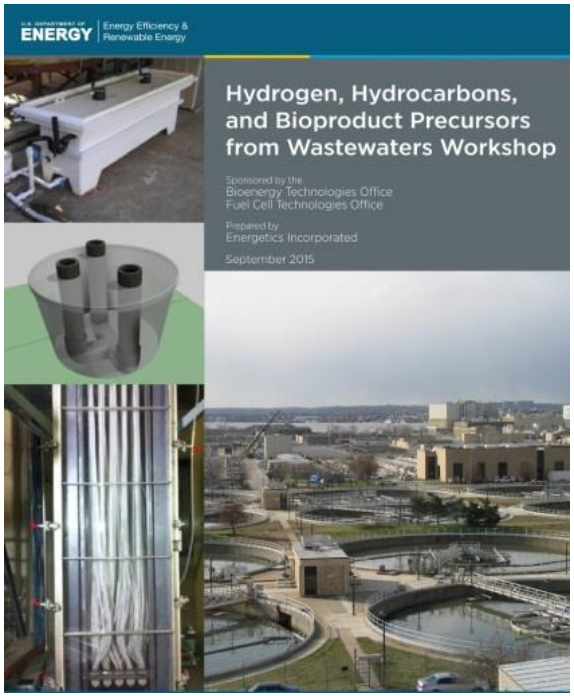
This **crosscutting project** simultaneously tackles **fuel and engine innovation** to **co-optimize performance** of both elements.

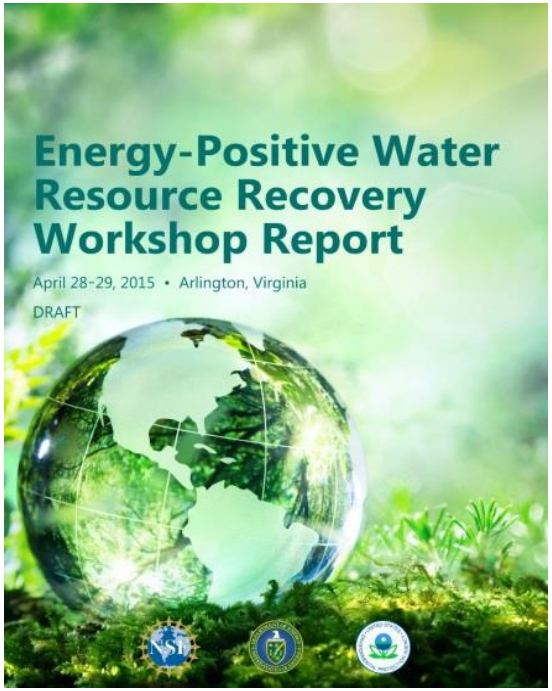
The project will provide industry with the R&D needed to:

- Bring **affordable and scalable near- and longer-term** biofuels and advanced engine solutions **to market more quickly**
- Reduce petroleum consumption by **billions of barrels a year**
- Improve fuel economy **15%–20% beyond projected results** of existing R&D efforts
- Deliver **tens of billions of dollars** in cost savings annually via improved fuel economy
- **Dramatically decrease** transportation sector criteria pollutants and GHG emissions.

Waste-to-Energy Activities, FY 15-17: Workshop Stream







- Series of three technically detailed workshops
- Solicit extensive stakeholder input
- Joint efforts with DOE Fuel Cells Office, EPA, and NSF
- Informing FY 16-17 DOE Waste-to-Energy Roadmap
- Also laid foundations for additional collaborations with NSF, EPA, and Water Environment Research Foundation (WERF)

Waste-to-Energy Activities, FY 15-17: Lab Projects (~$4M/year)

- Hydrothermal Liquefaction (hot, high pressure water) of biosolids to produce biofuels
- Microbial conversion of biogas to valuable bioproduct precursors
- Comprehensive resource assessment of wet and gaseous waste streams in the U.S.
- Production of higher value products than methane from anaerobic digestion of biosolids
- First three projects track to continue into FY 17
- Fourth ends in FY 16, labs will compete with new ideas

Synthetic Biology Foundry

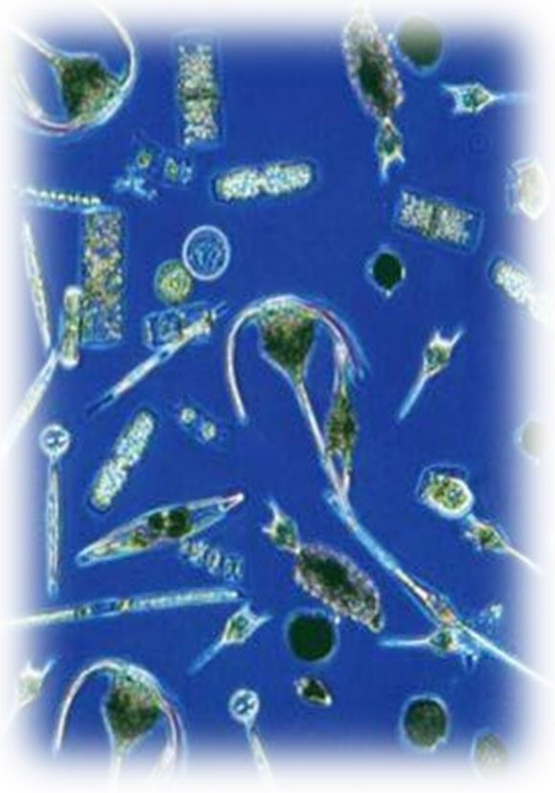
- A multi-lab Foundry to apply synthetic biology tools to modify organisms, and develop robust processing capabilities, and scale-up, which can be easily transferred to industry
- Engineering biology offers the potential to dramatically reduce the lead time and cost of bringing new renewable fuels and chemicals to market
- Development of publically available tools, host strains, and scaling methods is a national need
- The Foundry will enable:
  - Open strain-construction capability
  - High throughput capability to test thousands of organism designs per year
  - Significantly improved design-build-test-learn cycle over state-of-the-art
  - Capabilities to optimize molecule production from milligrams to hundreds of grams scale
  - Partnerships with many companies to identify and develop industrially-relevant host organisms
  - Resources for smaller/start-up companies to speed commercialization of new molecules and organisms

Upcoming Spring Workshops

Sharpening our Tools: Algal Biology Toolbox Workshop

The purpose of this workshop is to gather lead experts in the field of algal biology to discuss:

- The current state of algal biological tools, including our understanding of algal biology and biochemistry, available molecular toolboxes, 'omics databases, and other resources;
- Challenges to developing and applying a full suite of biology tools to improve algae performance and system robustness; and
- Strategies to advance progress towards commercial algal biofuels.



Save-the-date coming soon!

Upcoming Spring Workshops

Biorefinery Optimization Workshop

The purpose of this workshop is to gather information on challenges encountered with the successful scale-up and reliable operation of integrated biorefineries (IBR).

- The workshop will look at the broad scope of technology development seeking to understand the technical challenges that have hindered, or could in the future hinder, the achievement of advanced biorefinery development goals.
- The workshop will include all pathways, methods, and technologies employed to convert woody biomass, agricultural residues, dedicated energy crops, algae, municipal solid waste (MSW), sludge from wastewater treatment plants, and wet solids, into biofuels, biochemicals, and bioproducts.

Save-the-date coming soon!

Federal Activities Report on the Bioeconomy

- On February 18th, the Biomass R&D Board released the Federal Activities Report on the Bioeconomy (FARB).
- This report aims to educate the public on the wide-ranging, federally funded activities that are helping to bolster the bioeconomy.
- The FARB details a vision for a Billion Ton Bioeconomy—tripling the size of today's bioeconomy by 2030.
- Achieving this vision would provide economic, environmental, and social benefits, including a considerable reduction in GHG emissions.

2016 Billion Ton Update

- Draft of Volume I was completed in March of 2016.
  - Volume I will be released to the public in July of 2016.
  - BTU Team briefed BETO staff on Volume I on March 7th.
  - BTU Team will brief DAS Sarkar on Volume I on March 9th.
  - BTU Team will brief Dr. Danielson on Volume on I on March 14th.
- Volume II will not be complete until October of 2016.

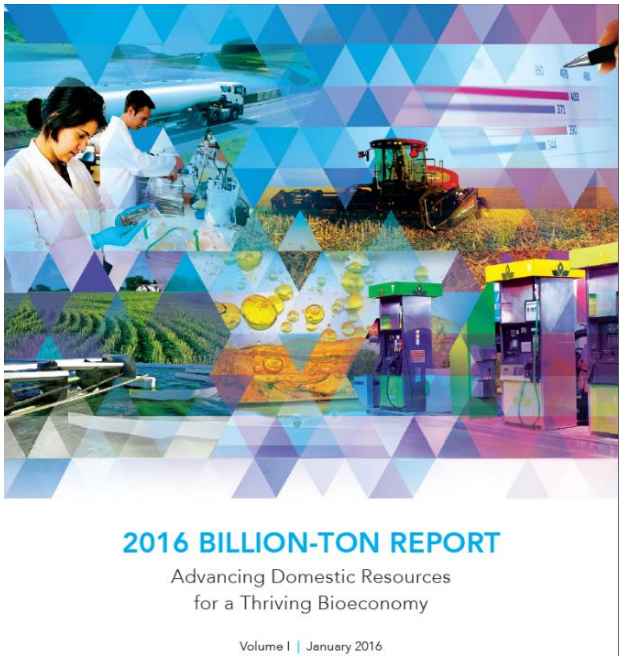
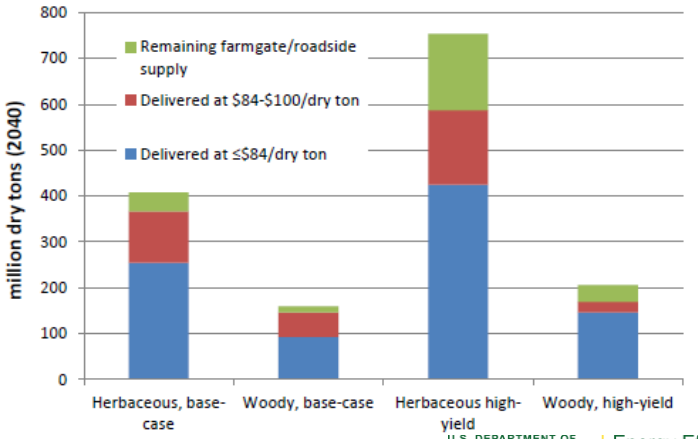


Figure ES.6 ⋮ Summary of 2040 herbaceous and woody supplies delivered at less than $84 per dry ton and $84–$100 per dry ton, as a fraction of total farmgate/roadside supplies, for base-case and high-yield scenarios



BETO Strategic Plan

Strategic Planning Process

- Numerous Focus Group meetings held March – August 2015
- Visioning Meeting held September 1-2, 2015 in Golden, CO; developed Vision 2040 and Mission statements
- Stakeholders meeting held on December 8, 2015, in Arlington, VA, with participants from DOE, national labs, industry, academia, and other federal agencies to develop Strategic Goals and Strategies
- A draft Strategic Plan is currently under development and will go through final development, internal review and approval process during April-June 2016
- The final Strategic Plan is scheduled for release in July 2016

BETO Lab Impacts and Tech-2-Market

EERE is focused on improving the intensity and frequency of Lab-industry engagement to produce more commercially-relevant R&D.

Two specific programs administered at the EERE level that BETO is actively participating in are:

- Small Business Voucher Program
  - Small Business Vouchers (SBV) Pilot matches selected clean energy small businesses with experts from the national labs—and give the businesses vouchers valued at $50K to $300K that they can exchange for national lab technical assistance.
  - BETO has already funded 2 projects with small businesses, with plans to fund up to 5-10 more
- LabCorps
  - Modeled after the successful NSF I-corps program, this "entrepreneurship boot camp" seeks to empower National Lab teams to more accurately identify market applications and private sector partners to commercialize BETO-funded Lab technology.
  - BETO will be funding one team with plans to fund up to 3-6 more teams

Extension of BETO's pilot "industrial seedling" program

- In FY15, BETO conducted a pilot "industrial seedling" program that provided up to $20K per project to the National Labs to solve specific problems for small businesses and lay the foundation for future collaboration.
- The intent of this program is to introduce small businesses to the DOE National Laboratories.
- In FY16, BETO will increase this program from 20K to 40K per project, incorporating feedback from the FY15 pilot.

Bioenergy 2016 and Sustainable Transportation Day

Bioenergy 2016

Dates:
July 12, 2016, Tuesday afternoon –
July 14, 2016, until Thursday noon

Location:
Walter E. Washington Convention Center
801 Mount Vernon Place, NW
Washington, DC 20001

Partnered with:
Clean Energy Research & Education Foundation

Sustainable Transportation Day

Dates:
July 11, 2016, Monday afternoon –
July 12, 2016, until Tuesday noon

Location:
Walter E. Washington Convention Center