



**Biomass R&D Technical
Advisory Committee (TAC)
March 5, 2015**

**Jonathan L. Male
Director, Bioenergy
Technologies Office**

Outline

- ❑ Overview
- ❑ Risk and Innovation
- ❑ FY14 Accomplishments
- ❑ FY15 Activities
- ❑ FY16 Proposed Activities
- ❑ Strategic Planning
- ❑ Upcoming BETO Events

Bioenergy Technologies Office (BETO)

Mission

Accelerate the commercialization of advanced biofuels and bioproducts through targeted research, development, and demonstration supported by public and private partnerships

Strategic Goal

Develop technologies to enable the sustainable, nationwide production of biofuels compatible with today's transportation infrastructure

Performance Goal

By 2017, validate a least one pathway for \$3/GGE* hydrocarbon biofuel (with ≥50% reduction in GHG emissions relative to petroleum)

*Mature modeled price at pilot scale.

Through RD&D, BETO reduces risks and costs to commercialization

The Challenge and the Opportunity

THE CHALLENGE

- U.S. gasoline consumption is 8.5 million barrels/day
- 67% of U.S. petroleum consumption is in the transportation sector



THE OPPORTUNITY

- More than 1 billion tons of biomass could be sustainably produced in the U.S.
- 1 billions tons of biomass could displace 30% of U.S. petroleum use by 2030



Biofuels could displace 30% of liquid transportation fuels

Bioenergy Technologies Office's Focus Areas

Program Portfolio Management

- Planning
 - MYPP
 - Competitive
- Systems-Level Analysis
 - Peer Review
 - Non-competitive
- Performance Validation and Assessment
 - Merit Review
 - Lab Capabilities Matrix
- Quarterly Portfolio Review



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

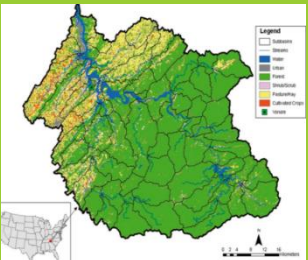
- Integrated Biorefineries
- Biofuels Distribution Infrastructure



Cross Cutting

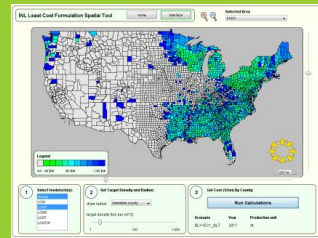
Sustainability

- Sustainability Analysis
- Sustainable System Design



Strategic Analysis

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



Strategic Communications

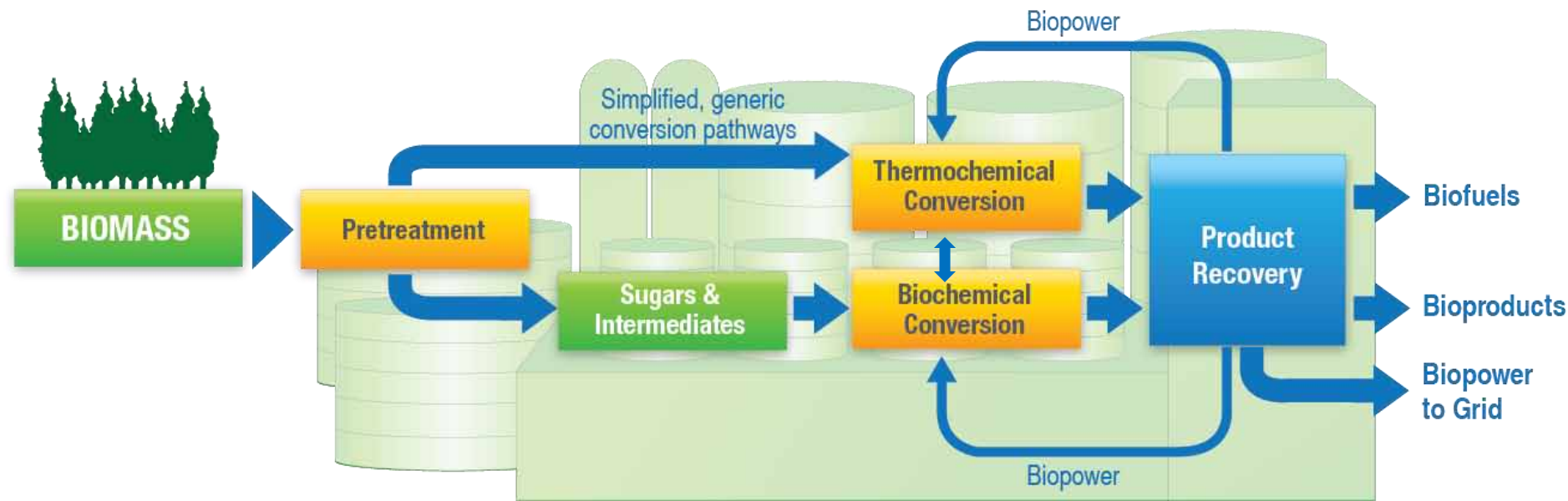
- New Communications Vehicles & Outlets
- Awareness and Support of Office
- Benefits of Bioenergy/Bioproducts



Key Challenge for Innovation Involves Lowering Risks

De-risking technologies is central to R&D through demonstration that addresses greater integration and scale:

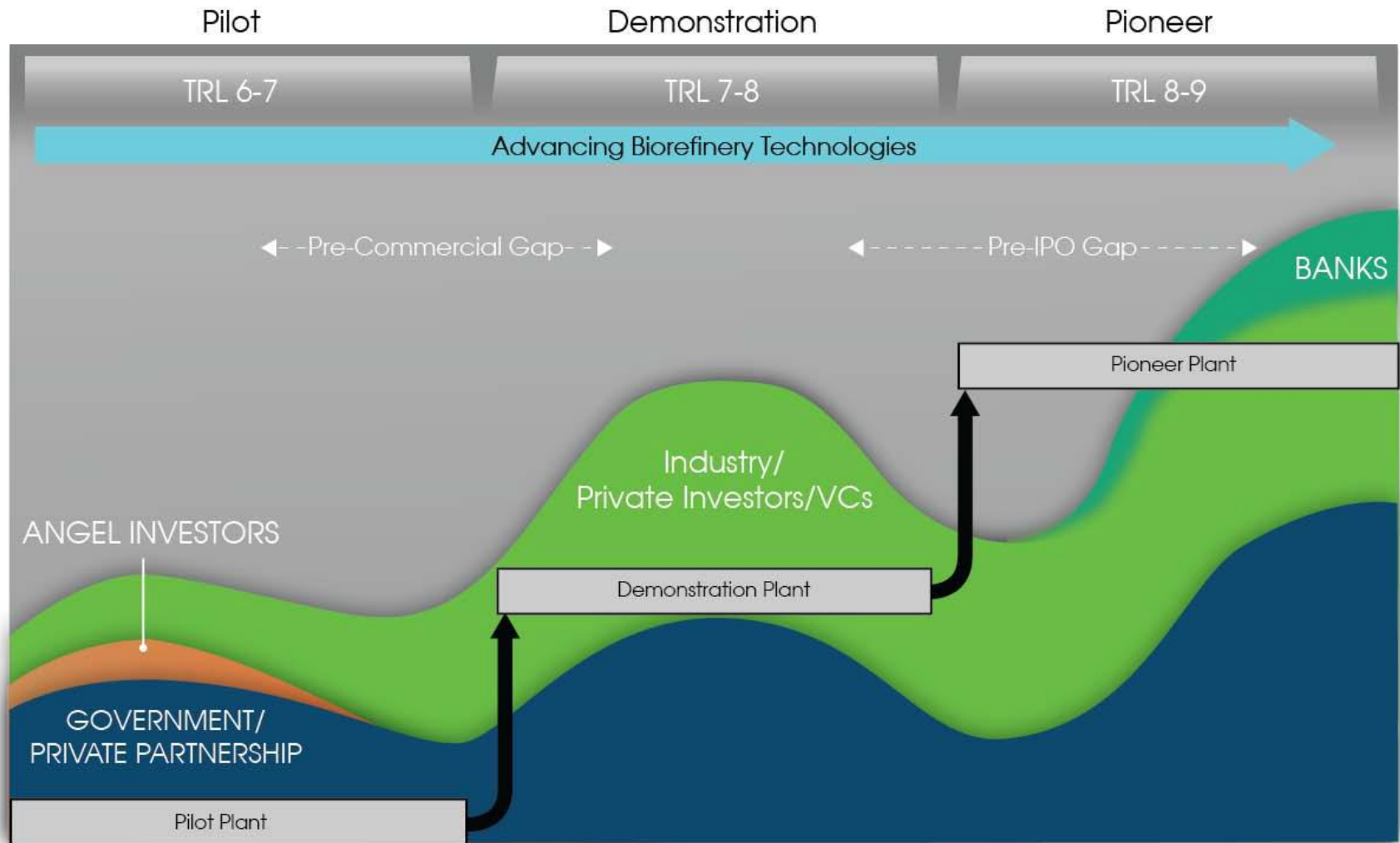
- BETO is focusing on advancing renewable gasoline, diesel, and jet fuels technologies.
- Technical, construction, operational and financial/market risks.



Key Challenges

Biomass	Pretreatment	Conversion	Product
<ul style="list-style-type: none">• Reliable supply• Consistent quality• Affordable delivery	<ul style="list-style-type: none">• Biomass feeding, sizing and moisture• Solids handling• Construction materials	<ul style="list-style-type: none">• Products Yields• Construction materials• Catalysts• Fermentation organisms	<ul style="list-style-type: none">• Separations• Catalytic upgrading• Recycle loops

Valley of Death



BETO supports cost shared first-of-its-kind facilities to de-risk new technologies and bring industry past the valley of death.

2014 BETO R&D Accomplishments

- **Significant Cost Reductions were Achieved in Feedstock Logistics Project:**
 - BETO's 5 high-tonnage feedstock logistics projects (which included partnerships with original equipment manufacturers) demonstrated significant cost-reductions, of approximately \$13 per dry ton.
- **Significant Progress was Achieved in Reducing Conversion Costs for Advanced Biofuels:**
 - Specifically in FY14, BETO's thermochemical conversion R&D achieved a \$4.09 per gallons gasoline equivalent (GGE), which translates to a fuel selling price of \$5.26 per GGE (a reduction of \$0.51 from FY13), based on an nth plant modelled cost.
 - NREL demonstrated an innovative technology to deconstruct and selectively convert lignin to key intermediates on a pathway to valorize lignin.
- **New Analysis/Tools were developed to Quantify and Improve the Environmental Performance of Cellulosic Feedstock Production:**
 - BETO worked with ANL to release WATER 2.0, the first national scale U.S.-centered model for quantifying the water footprint of various biofuel pathways at the county level, which will advance responsible deployment of bioenergy under water constraints by providing analytical and decision support to industry stakeholders and policymakers.
- **The National Alliance for Advanced Biofuels and Bioproducts (NAABB) Consortium Published its Final Report with Major Findings for Algal Research:**
 - In three years, NAABB was able to develop technologies that have the potential to reduce the cost of algae-based biocrude by two orders of magnitude from our starting baseline [the Aquatic Species Program]; that is, from \$240 to \$7.50 per gallon.

Feedstock Accomplishments

Sun Grant Regional Feedstock Partnership

- Network of land-grant universities working in partnership with DOE, industry, national labs, and USDA to establish over 100 field trials across the country to determine biomass productivity baselines of energy crops.
- Maps of crop productivity contribute data to Oak Ridge National Laboratory's Bioenergy Knowledge Discovery Framework (KDF).

<https://www.bioenergykdf.net/>

Advanced Logistical Systems and Harvesting Technologies

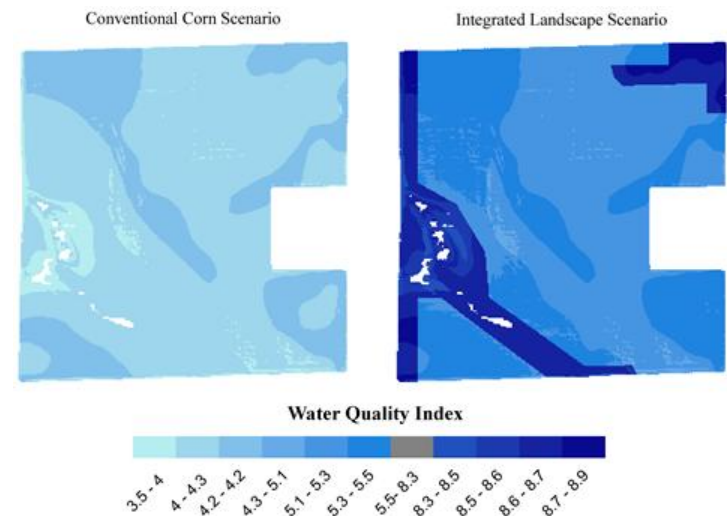
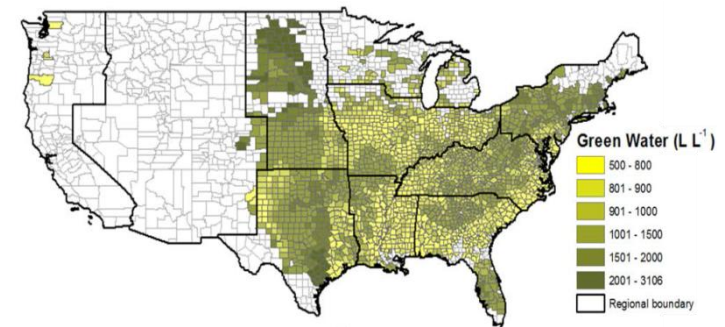
- AGCO (with partners) received an award in 2009 to demonstrate an efficient harvesting and transport system for corn stover and other herbaceous feedstocks.
- As a result of this project, several technologies were developed, including:
 - Single pass combo Combine-Baler (which increased bale density by 15%).
 - High MOG (Material Other than Grain) Combine.



FY14 Technical Highlights and Accomplishments

FY14 MYPP milestone: *By 2014, quantify the water footprint of cellulosic feedstocks at the county level, and identify modeled feedstock production systems that increase energy crop production and agricultural residue removal by 50%, increase soil quality by at least 5%, and improve water quality compared to traditional agricultural management*

- Released **WATER** (web-based water footprint tool) version 2.0, which includes new perennial grass pathways with six BT2 scenarios for switchgrass- and miscanthus-derived biofuel. (ANL)
- Completed case study of optimized subfield-scale and county-scale landscape designs in Iowa that increased biomass availability (>50%) by integrating switchgrass and residue removal into conventional row crop landscape. (INL)
 - Field scale: improved the annual rate of soil organic carbon gain by 69%, reduced annual soil erosion by 63%, and increased the Water Quality Index from 4.1 to 6.0.
 - County scale: increased average soil organic matter by 158%, reduced nutrient loss by 21%, reduced risk to surface waters by 27%.



BCU Selection Announcement

On October 9th, DOE announced up to \$13.4 million for five projects to develop advanced biofuels and bioproducts that will help drive down the cost of producing gasoline, diesel, and jet fuel from biomass.

- **The University of Wisconsin** of Madison, Wisconsin will receive up to \$3.3 million to develop a process to produce high value chemicals from biomass, which can be used as plasticizers (an additive in certain plastics) and in the production of industrial chemicals and resins.
- **American Process, Inc.** of Atlanta, Georgia will receive up to \$3.1 million to develop and demonstrate processes to upgrade cellulosic sugars to solvents in their demonstration facility.
- **The National Renewable Energy Laboratory** of Golden, Colorado will receive up to \$2.5 million to develop a conversion process demonstrating the production of muconic acid from biogas. This acid can be converted into an array of bioproducts, including fuel, plasticizers, and lubricants.
- **Natureworks, LLC** of Minnetonka, Minnesota will receive up to \$2.5 million to develop a fermentation process, using biogas and bacteria, for the production of lactic acid. This process could be used for the commercialization of biomethane to fuels.
- **Vertimass LLC** of Irvine, California will receive up to \$2 million to commercialize technology to convert ethanol into diesel fuel, gasoline, and jet fuel blend stocks compatible with the current transportation fuel infrastructure.

FY15 Program Activities and Goals

Feedstocks: Demonstrate a modeled mature delivered feedstock cost of \$115 per dry matter ton (including both grower payment and logistics).

Algae: Demonstrate integrated protein and carbohydrate conversion with target of 80% of theoretical yield from proteins and carbohydrates. Demonstrate an increase in algal intermediate yields (1,500 gallons/acre/year).

Demonstration and Market Transformation: Increase portfolio to include 3 novel technology demonstrations to reduce risk of scale up of emerging bioenergy pathways.

Biochemical Conversion: Reduce modeled conversion cost via a biochemical (hydrolysis) conversion route to hydrocarbon fuel blendstocks in support of the 2022 programmatic goal of \$3/gal for drop-in fuels such as renewable gasoline, diesel, and jet fuel [\$6.40/gallon of gasoline equivalent (gge)].

Thermochemical Conversion: Reduce the modeled conversion cost contribution via fast pyrolysis for converting biomass to a hydrocarbon fuel blendstock in a mature commercial-scale plant. [\$3.70/gallon of gasoline equivalent (gge)].

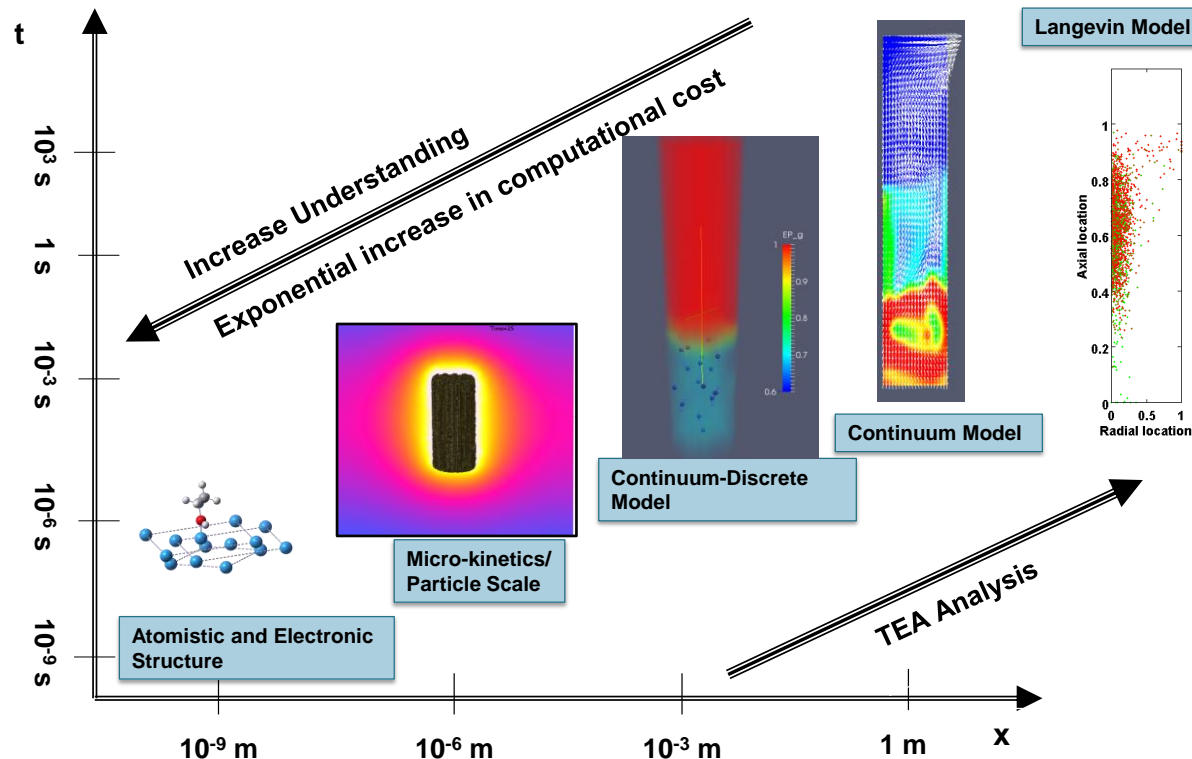
Sustainability: Identify practices that improve sustainability and environmental performance of advanced bioenergy, including results from a comprehensive case study of environmental, social, and economic sustainability indicators for a cellulosic feedstock production and biorefinery system.

Collaborations with the Vehicle Technologies Office: Test fuels and develop better engines for high octane fuels.

Computational Pyrolysis Consortium

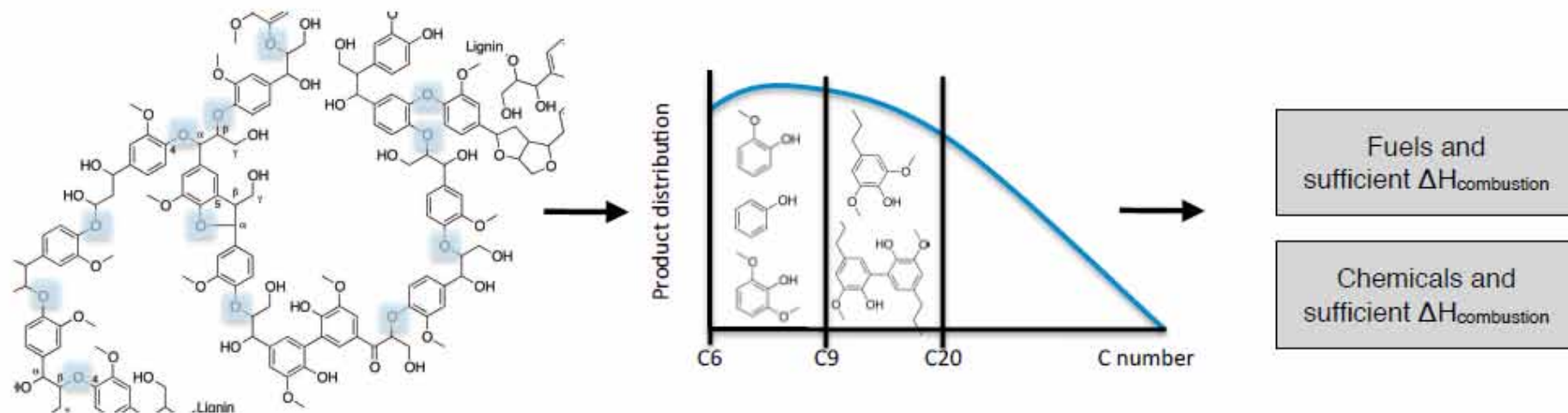
Combined effort between ORNL, NREL, PNNL, INL, and ANL (FY14 \$2.7M total).

- Organized around six tasks lead by different labs. Aims to facilitate sharing of specialized tools and capabilities amongst collaborators and the public.
- Focused on accelerating the advancement of condensed phase upgrading technologies for bio oils to liquid transportation fuels, enabling them to more rapidly overcome existing barriers to commercialization and cost competitiveness.



Lignin Valorization at NREL

TEA shows that lignin utilization is essential to meet \$3/gge target in 2022 (Davis et al., 2013)



Depolymerization

- Obtain lignin in liquid phase at high yield
- Quantify/understand impact to polysaccharides

Upgrading

- Convert lignin to fuels and chemicals
- Leverage known deconstruction methods
- Develop new upgrading processes

De-polymerization and upgrading (from NREL - Lignin valorization through integrated deconstruction, biological funneling, and catalysis, Gregg T. Beckham)

Major Commercial-scale Cellulosic Ethanol Projects

POET-DSM's Project LIBERTY

- Grand opening on September 3, 2014, in Emmetsburg, Iowa.
- Once operating at full, commercial-scale, the plant will produce 25 million gallons of cellulosic ethanol per year – enough to avoid approximately 210,000 tons of CO₂ emissions annually.
- Developed with the support of approximately \$100 million in investments and research from DOE.



Abengoa Bioenergy Biomass of Kansas

- Grand opening on October 17, 2014, in Hugoton, Kansas.
- The plant will produce cellulosic ethanol from non-edible corn stalks, stems, and leaves harvested within a 50-mile radius of the plant.



Demonstration Portfolio – Selected Pilot Projects

American Process, Inc., Alpena, MI

- Feedstock: waste stream from hardboard manufacturing
- Capacity: 894,200 gal/yr of cellulosic ethanol (from C6 sugars) and 696,000 gal/yr of aqueous potassium acetate (De-Icer) (from C5 sugars).
- Accomplishments:
- First batch of cellulosic ethanol produced in FY14
- The project's capacity is 800,000 gallons per year.
- DOE share: \$22,481,523; Cost share: \$8,459,327.

Haldor Topsoe, Inc., Des Plaines, IL

- Thermochemical conversion of wood waste and woody biomass to gasoline.
- This project is expected to produce 345,000 gallons per year.
- Accomplishments :
 - Testing shows acceptable ranges for gasoline blendstock.
 - Emission level was similar to gasoline.
- DOE share: \$25,000,000; Cost share: \$9,388,778
- Collaborative agreements with Gas Technology Institute, Andritz-Carbona, UPM-Kymmene, and Phillips 66.



Bioenergy Technologies Office Incubator Selections

On February 20, 2015 DOE announced up to \$10 million for seven projects to support innovative technologies that are not represented in a significant way in the Bioenergy Technologies Office's current project portfolio:






- **Metabolix, Inc.** of Cambridge, MA, will receive up to \$2 million to develop a non-genetically modified, non-food feedstock, *Camelina sativa*, to maximize oil yields per acre.
- **The Pacific Northwest National Laboratory** of Richland, WA, will receive up to \$900,000 to develop a process to allow microalgae production directly from CO₂ in air at high productivities.
- **The Ohio State University** of Columbus, OH, will receive up to \$1.2 million to develop a process cellulosic butanol production process through novel metabolic engineering of two different pathways.
- **The University of California Riverside** of Riverside, CA, will receive up to \$1 million to further develop a co-solvent pretreatment to high yields of clean fuel precursor fractions.
- **OPX Biotechnologies** of Boulder, CO, will receive up to \$2 million to develop the production of cost-competitive C₈ fatty acid derivatives from cellulosic sugars via novel metabolic engineering pathways.
- **Kiverdi, Inc.** of Berkeley, CA, will receive up to \$2 million to further develop process methods and genetic tools for the production of hydrocarbons in thermophilic bacteria that directly utilizes biomass-derived syngas .
- **Gas Technology Institute** of Des Plaines, IL, will receive up to \$1.4 million to develop a process to catalytically convert biomass plus methane into very high yields of hydrocarbon liquid fuels and chemicals.

Defense Production Act (DPA) Initiative

In September 2014, three 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 (w/o subsidies)



Company	Location	Feedstock	Capacity	Groundbreakin g	Off-Take Agreements
	Gulf Coast	Fats and Greases	82.0 MM g/y	TBA	TBD
	McCarran, NV	MSW	10.0 MM g/y	Spring/Summer of 2015	 CATHAY PACIFIC
	Lakeview, OR	Woody Biomass	12.0 MM g/y	TBA	 SOUTHWEST AIRLINES

Interagency initiative to commercialize advanced biofuels

FY16 Budget Request to Congress

Program Area	FY 2014 Enacted*	FY 2015 Enacted*	FY 2016 Request*	FY 2016 vs. FY 2015*
Feedstocks	46,972	32,000	38,800	+6,800
Conversion Technologies	101,384	95,800	99,186	+3,386
Demonstration and Market Transformation	64,790	79,700	87,514	+7,814
Strategic Analysis and Cross-Cutting Sustainability	12,146	11,000	14,000	+3,000
Biopower	1,998	0	0	0
NREL Site-Wide Facility Support	5,000	6,500	6,500	0
Total, Bioenergy Technologies	232,290	225,000	246,000	+21,000

*Dollars in thousands

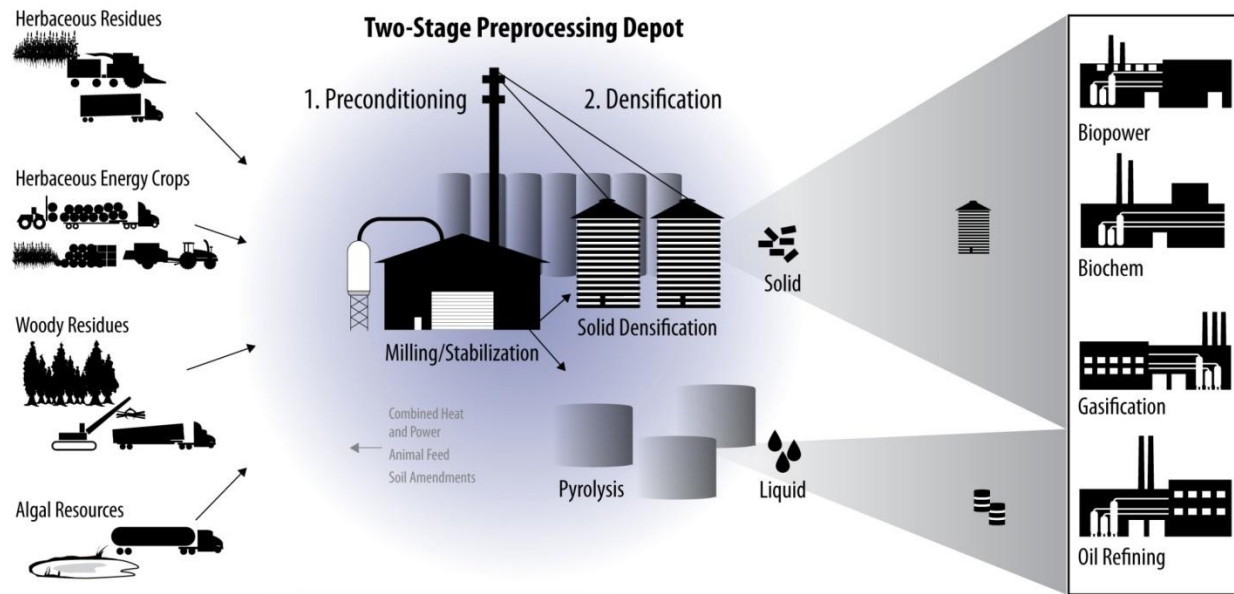
FY 2016 Priority Activities

- **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 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.

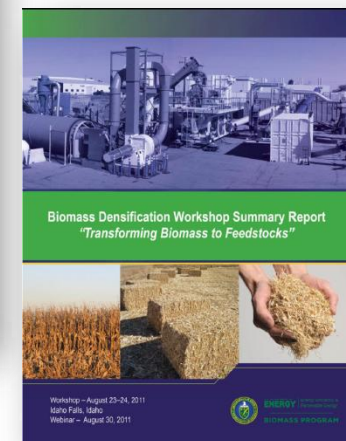
Advanced Supply System Design

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

- Actively manage feedstock variability and supply uncertainty
- Feedstock specifications and conversion performance drive logistics and preprocessing
- Advanced preprocessing accesses low-grade and diffuse resources (i.e., use any and all available resources)



Approach: Advanced preprocessing and formulation of multiple raw biomass resources into least cost/performance-based feedstocks



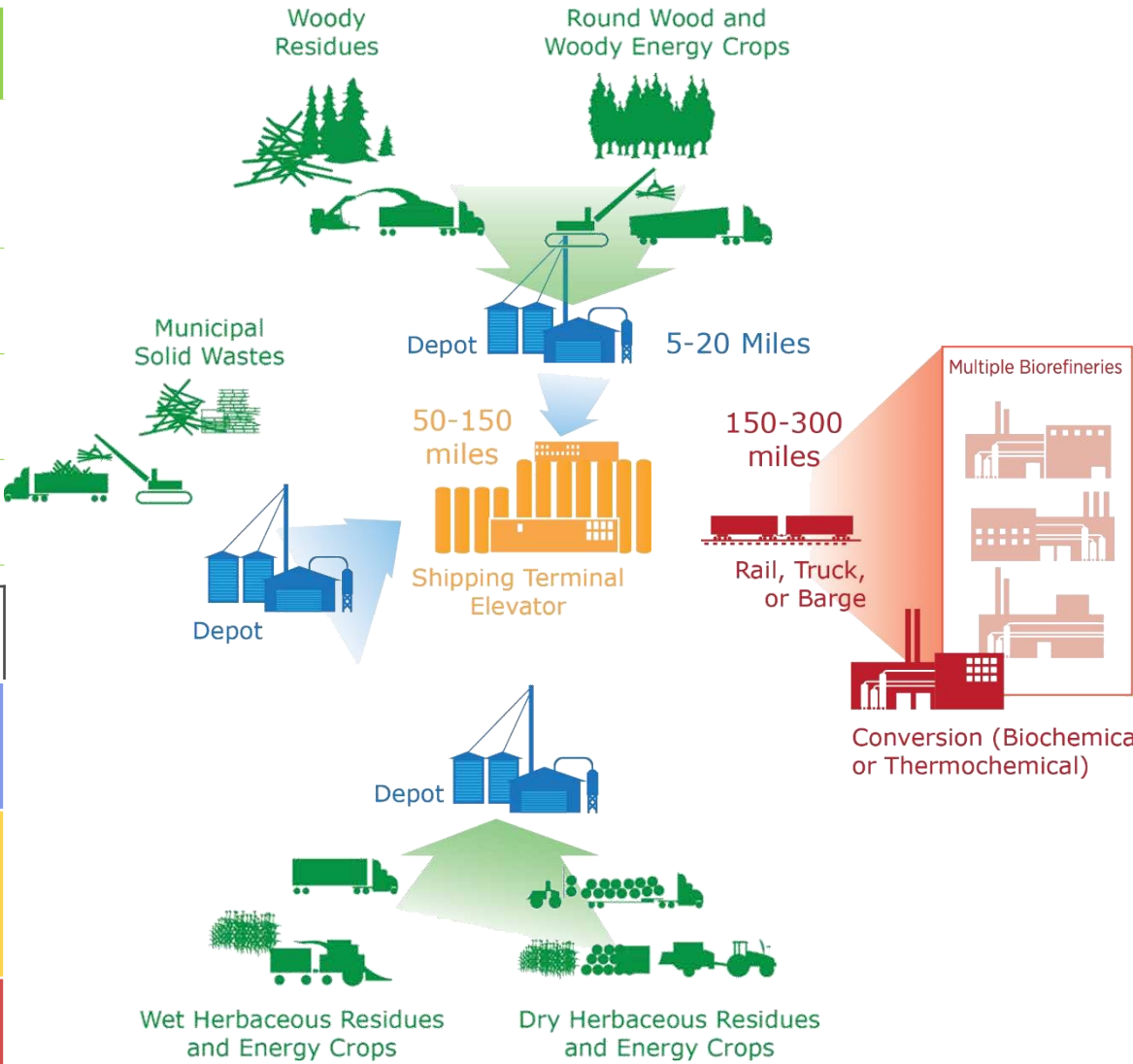
Biorefinery Scale >800 K tons/year

Commodity Vision for Infrastructure Compatibility

Commodity Attributes

- Standardized material formats are compatible with existing solid and liquid supply handling systems and infrastructures
- Feedstock quality is assured through national and international standards
- National market systems secure supply and demand in a sustainable way
- Biomass feedstocks futures contracts are tradable on commodity exchanges.

Infrastructure Boundaries (Solid System Example)
Production to Preprocessing Depot (5 to 20-mile radius) Field trucks
Preprocessing Depot to Terminal (50 to 150-mile radius) Interstate trucks, short line railroad, internal waterway transport systems
Terminal to Biorefineries (150 to 300+-mile radius) Trans/intercontinental shipping systems (e.g., unit trains, ocean barges, and freightliners)



Tech-to-Market Activities for the National Labs

Activity	Recipient	Funding	Total
Introducing Local Small Businesses to the National Labs	20 competitively selected projects	\$20K per project	\$400K
Industry/Innovation Day for all the Labs	1-2 competitively selected projects	\$100-50K per project	\$100K

National Lab Small Business Voucher Program



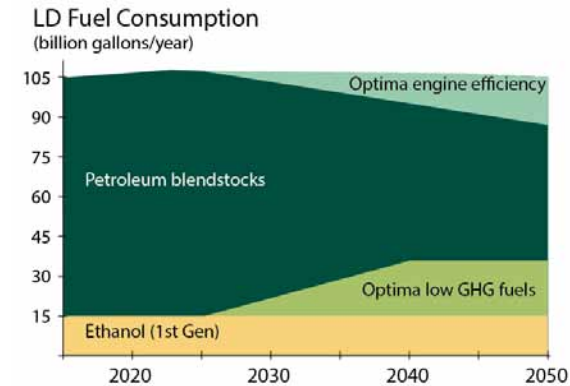
- Encourage labs to reach out to and assist small businesses.
- Strengthen U.S. economic competitiveness.
- Broaden access to national laboratory capabilities

New Fuels-Vehicles Systems Optima: Status and Next Steps

The Challenge: 80% reduction in transportation GHG by 2050

Status

- Optima included in President's FY16 budget at \$27M (\$17M VTO + \$10M BETO)
- Selected as lead Transportation "Big Idea" candidate
- Selected for presentation at April 2015 Big Idea Summit



Next Steps

- Stakeholder outreach
- Visits to auto-, energy-companies and biofuel companies ongoing since December
- Planning underway for stakeholder workshop / "listening day"
- Coordinate with complementary efforts (e.g., U.S. DRIVE)
- Develop detailed R&D plans

24 **co-optimize fuels and engines**



BETO New Areas Interests

1. Distillates (diesel and jet fuel)

- Address the non-light duty market by expanding collaborations into the aviation, marine, rail, trucking fields.
- Includes the need for production of bio-derived jet fuel in sufficient quantities to enable testing and certification of new fuels via the ASTM process.

2. Bioproducts

- Continuing to look into bio-products as long as they enable biofuels.
- Includes both the development and testing of bio-products (including animal feed and fish feed) from algae.

3. Natural Gas and Biogas

- The potential to co-utilize natural gas and biogas to produce fuels and chemicals via the gas/biomass to liquids (GBTL) processes.
- The development of distributed scale GBTL units that are skid mounted and mobile to utilize flared natural gas and bio-gas resources.

4. Infrastructure Needs

- Additional investments in infrastructure (rail, ports, barge, dams, inland waterways) to move biofuels (and other commodities) efficiently into market.

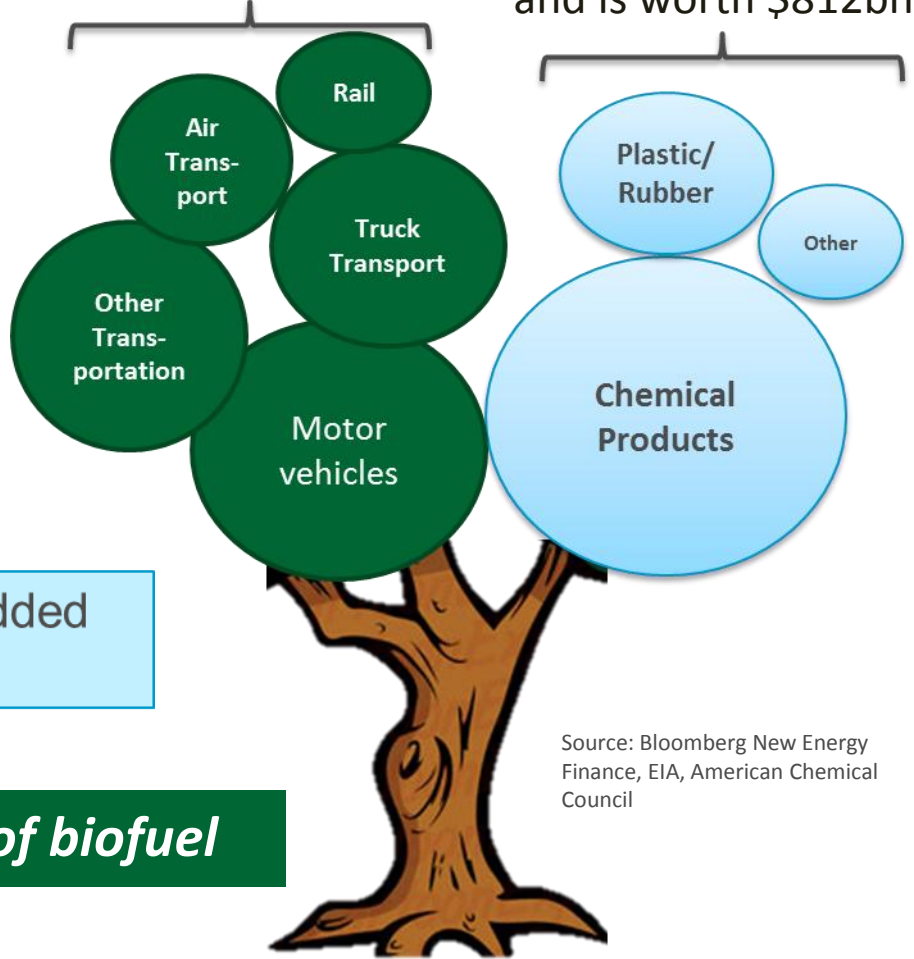
Oil products in the US: Opportunity for Bioproducts in the Bioeconomy

- The US produces 15% of global chemicals and chemicals comprise 12% of all US exports.
- The US produces: ethylene, propylene, polyethylene, butadiene, butanol, polystyrene, EO, MEG
- These chemicals are converted to: plastics, cosmetics, pharmaceuticals, detergents, packaging, clothing, car parts

Bioproducts provide much higher value-added margins, relative to transportation fuels.

Fuel makes up 76% of the volume of US oil products and is worth \$935bn

Chemicals make up 16% of the volume of US oil products and is worth \$812bn

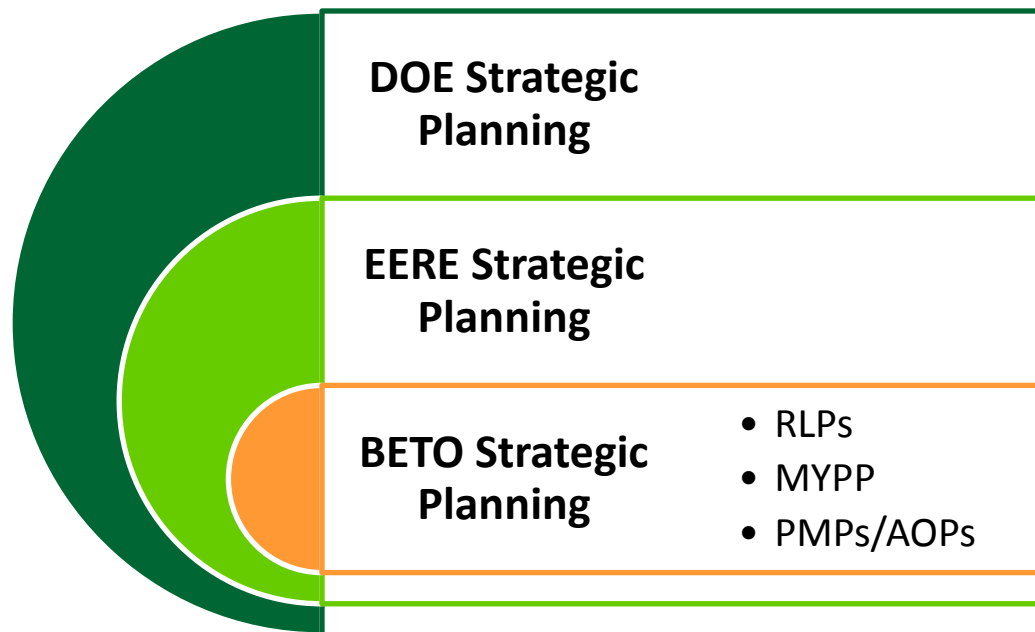


Source: Bloomberg New Energy Finance, EIA, American Chemical Council

Bioproducts enhance the economics of biofuel

BETO Strategic Planning

- Continuous process
- Provides framework
 - Alignment with EERE/DOE/Federal goals
 - Interactions with stakeholders
 - Inter- and intra-office collaborations/discussions across technology areas
 - Align Office activities from project level to multi-year goal horizons



BETO Strategic and Long-term Planning

- Purpose:
 - Align objectives and activities across multiple stakeholders and interests
 - Document goals, current state of technology, and strategic plans
 - Inform budget processes
 - Track progress
 - Integrate learning
- Based on best practices for technology R&D planning & systems engineering



The Baseline Bioeconomy

Biofuels

- Ethanol based, transitioning to drop-in
- Policy driven

Biopower

- Mostly wood wastes and wood
- Historically industrial heat, steam, and electricity

Bioproducts

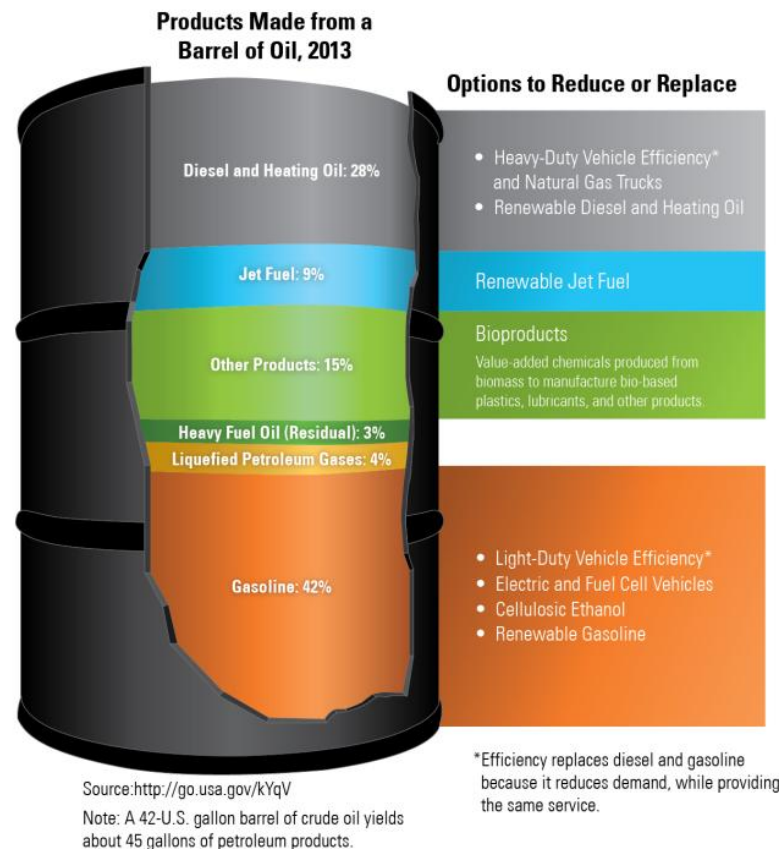
- Initially starch-based, transitioning to cellulosic

Bioeconomy Parameter	Current
Biomass Utilization	200 million DMT
Biopower Production (EIA)	30 billion kWh
Biofuels Production	15 billion gallons
Bioproducts Production	2.5 billion pounds
Direct Revenue	\$40 billion
Total (Direct + Indirect) Revenue	\$100 billion
Direct Jobs	150,000
Total (Direct + Indirect) Jobs	480,000
Estimated CO ₂ e Reduction	35 million tons

Estimates are 2011 and based on various assumptions and sources that may not be consistent with other published sources.

2015 Agricultural Outlook Forum, February 20, 2015,
Growing the Bioeconomy

Reducing and Replacing Petroleum Use



Upcoming Events and Publications

Waste-to-Energy (WTE) Workshop Series

- BETO/FCTO Workshop planned for March 18-19, 2015
Hydrogen, Hydrocarbons, and Bioproduct Precursors from Wastewaters
- Water Environment Research Foundation (WERF) workshop at Water and Energy/Residuals and Biosolids event in June 7-10, 2015

Publications

- Updated version of the Office's Multi-Year Program Plan was released in November. <http://www.energy.gov/eere/bioenergy/downloads/bioenergy-technologies-office-multi-year-program-plan-november-2014-update>
- New version is scheduled for release in April; will contain an assessment of additional pathways.
- A new version of the Update to the Billion-Ton Study is under-development.

Upcoming Events in BETO

Peer Review 2015

- Peer Review of BETO projects scheduled for March 23-25, 2015, Alexandria, VA
- Program areas include: Feedstock Production and Logistics, Algae, Biochemical Conversion, Thermochemical Conversion, Feedstock Production and Logistics, Analysis and Sustainability, and Demonstration and Market Transformation.
- <http://www.energy.gov/eere/bioenergy/2015-project-peer-review>

Bioenergy 2015: *Opportunities in a Changing Energy Landscape*

- Scheduled for June 23-24, 2015, Washington DC Convention Center.
- Bioenergy 2015 will convene key representatives from across the bioenergy supply chain, including industry, federal agencies, universities, and Congress.
- Focus on what is needed to sustain the growth and success of the advanced bioenergy industry now, and into the future.

