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**Agricultural Outlook Forum
February 20, 2015**

**Jonathan Male
Director, Bioenergy
Technologies Office (BETO)**

Outline

- I. Overview
- II. The U.S. Bioeconomy
- III. Feedstock Supply Systems
- IV. Demonstration Portfolio
- V. Major Initiatives
- VI. FY15 Awards and Funding Opportunities
- VII. FY16 Priority Areas
- VIII. Upcoming Events

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.

The Challenge and The Opportunity

The Challenge

- More than 13 million barrels of petroleum based fuels are required daily for the U.S. transportation sector – 8.5 million barrels of gasoline for the motor vehicles alone.¹
- 76 % of U.S. petroleum consumption is in the transportation sector (\$935 billion)²
- 16% of U.S. petroleum consumption is for chemicals and products sector (\$812 billion)²
 - Relative value is much higher for chemicals and products.

The Opportunity

- Biomass is the leading renewable resource that can provide drop-in fuel replacements utilizing existing infrastructure for light and heavy duty vehicles and air transportation¹
- More than 1 billion tons of sustainable biomass could be produced in the U.S. which can provide fuel for vehicles and aviation, make chemicals, and produce power for the grid.
- 30% of U.S. petroleum usage could be displaced using terrestrial biomass by 2030³
 - This does NOT take into account algae
- High value chemicals and products from biomass can stimulate biofuels production.

¹ Energy Information Administration, 2012 Energy Review, U.S. Department of Energy, 2013

² Bloomberg New Energy Finance, EIA, American Chemical Council

³ Update to the Billion-ton Study, U.S. Department of Energy, 2011

BETO's 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

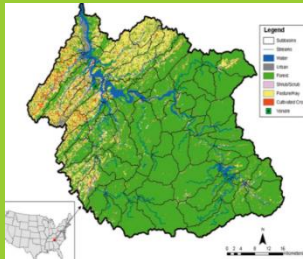
- Integrated Biorefineries
- Biofuels Distribution Infrastructure



Cross Cutting

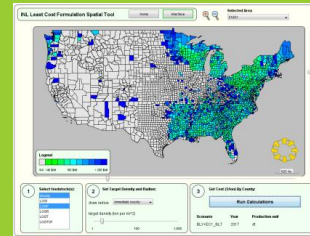
Sustainability

- Sustainability Analysis
- Sustainable System Design



Strategic Analysis

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



Strategic Communications

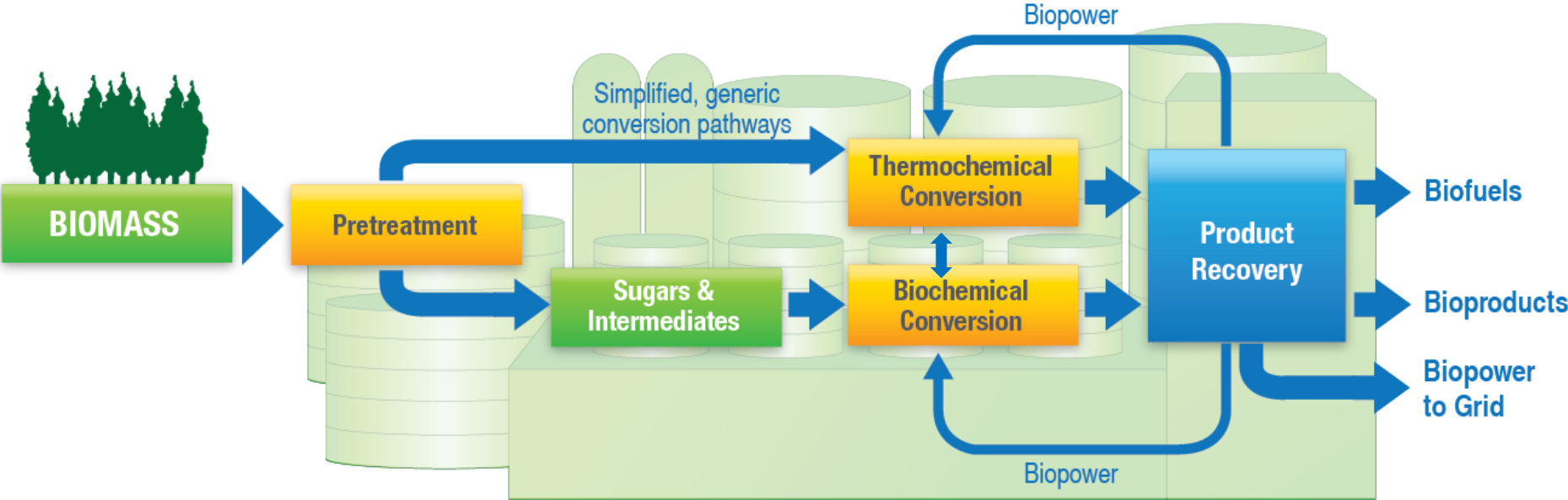
- New Communications Vehicles & Outlets
- Awareness and Support of Office
- Benefits of Bioenergy/Bioproducts



Key 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

What is the Bioeconomy?

“The biological sciences are adding value to a host of products and services, producing what some have labelled the “bioeconomy.” From a broad economic perspective, the bioeconomy refers to the set of economic activities relating to the invention, development, production and use of biological products and processes.”

OECD: The Bioeconomy to 2030: Designing a Policy Agenda, 2009

“A bioeconomy is one based on the use of research and innovation in the biological sciences to create economic activity and public benefit.”

White House Bioeconomy Blueprint, 2012

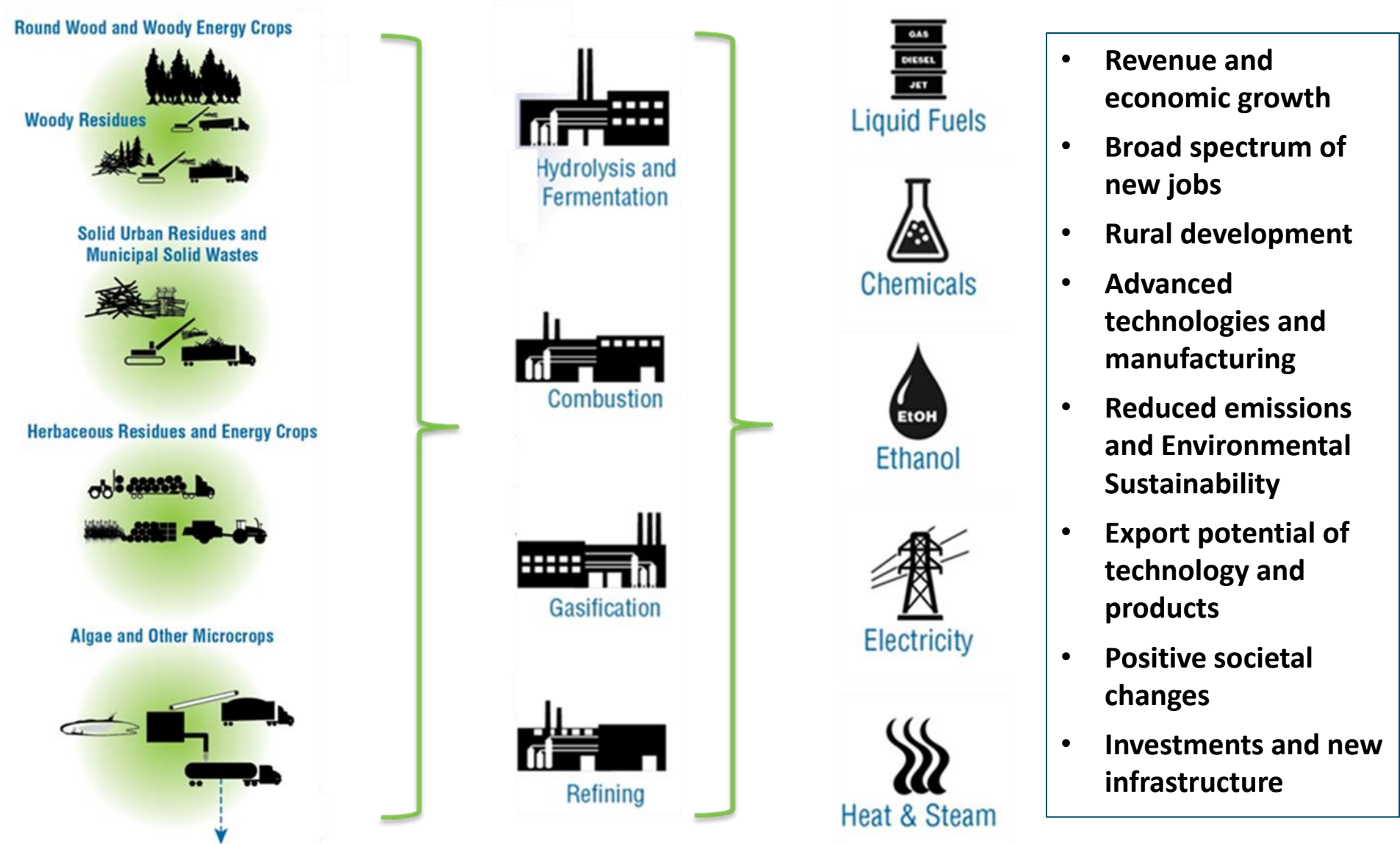
“The U.S. is a world leader in technology and agricultural prowess, which puts it in a powerful position to capitalize on the vast potential of bio-based alternatives to petrochemicals. The potential markets are huge, given the importance of petrochemicals in industrial economies.”

Unleashing the Power of the Bio-economy, 2013

For the purpose of this presentation, the “bioeconomy” is defined “the global industrial transition of sustainably utilizing renewable aquatic and terrestrial biomass resources in energy, intermediate, and final products for economic, environmental, social, and national security benefits.”

--From 2014 Report: Why Biobased? Opportunities in the Emerging Bioeconomy: Why BioPreferred

The Bioeconomy Concept



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 dry matter tons
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

Full information and sources available:

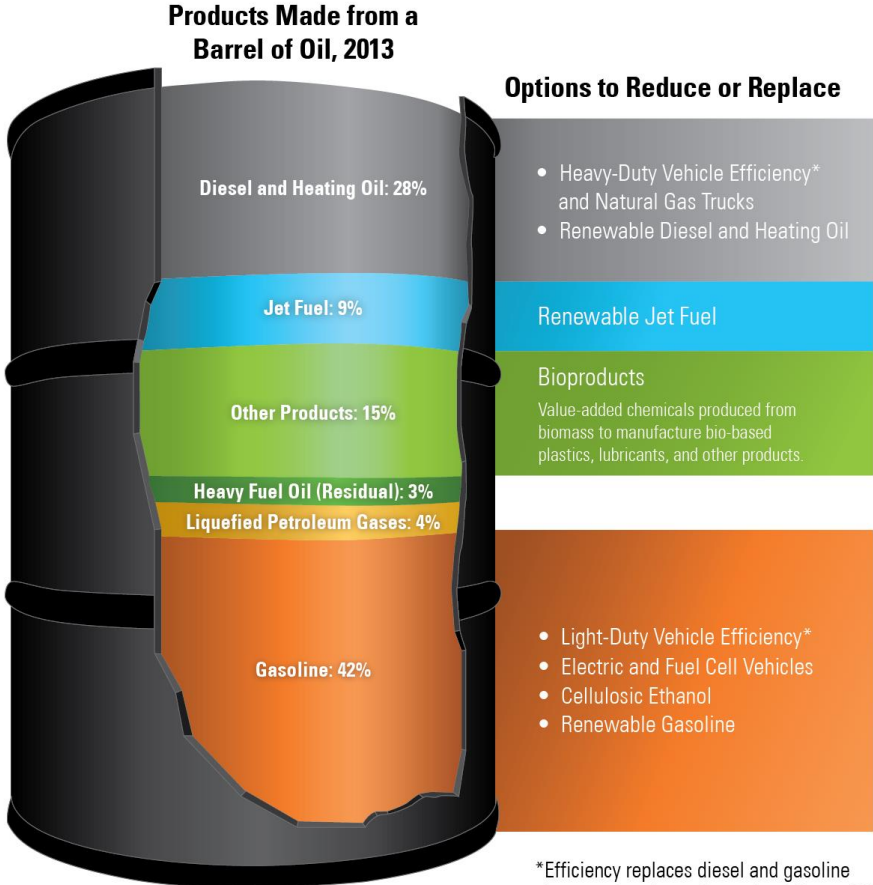
http://www1.eere.energy.gov/biomass/pdfs/billion_ton_update.pdf; https://www1.eere.energy.gov/bioenergy/pdfs/mypp_may_2013.pdf;
<http://www.eia.gov/forecasts/aeo/er/index.cfm>; <http://www.iea.org/techno/essentials3.pdf>; <http://www.bio.org/sites/default/files/EconomicImpactAdvancedBiofuels.pdf>;
<http://www.bio.org/sites/default/files/EconomicImpactAdvancedBiofuels.pdf>; <http://www.ers.usda.gov/publications/err-economic-research-report/err159.aspx#.UugtsRAo5pg>;
<http://www.bls.gov/green/biofuels/biofuels.pdf>; <http://www.eia.gov/forecasts/aeo/er/index.cfm>

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 \$1 Billion each day on crude oil imports.*
- Only about 40% of a barrel of crude oil is used to produce petroleum gasoline.
- Cellulosic ethanol 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.

Reducing and Replacing Petroleum Use



Source: <http://go.usa.gov/kYqV>
Note: A 42-U.S. gallon barrel of crude oil yields about 45 gallons of petroleum products.

*Efficiency replaces diesel and gasoline because it reduces demand, while providing the same service.

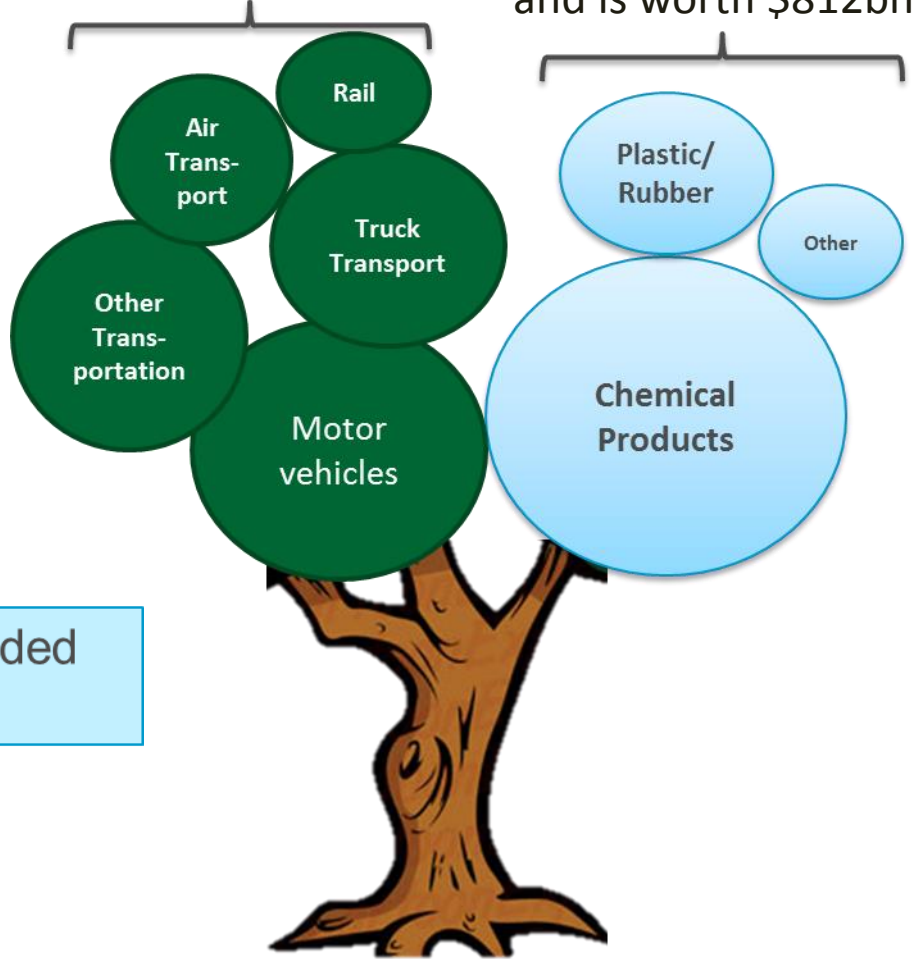
A 42-gallon (U.S.) barrel of crude oil yields about 45 gallons of petroleum products.

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

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



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

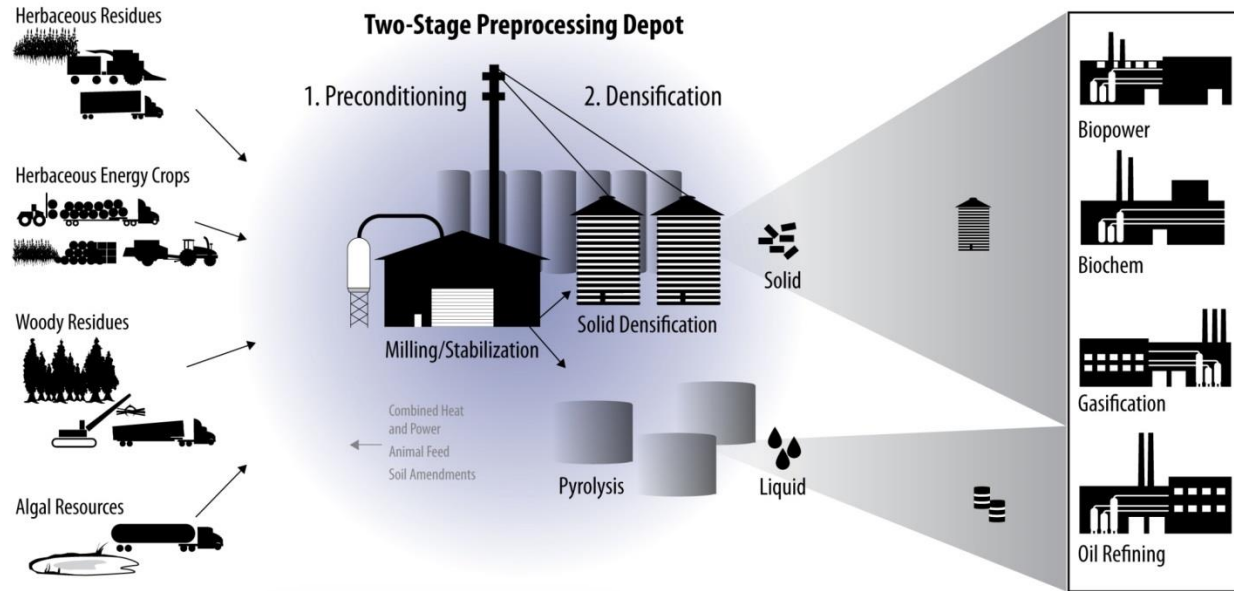
Source: Bloomberg New Energy Finance, EIA, American Chemical Council

Advanced Supply System Design

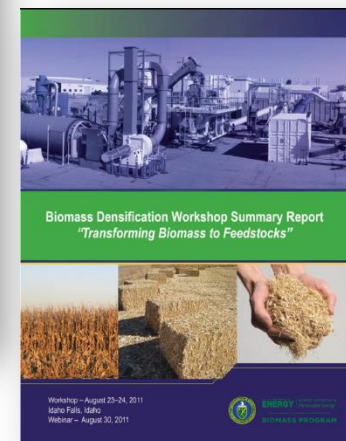
Objective: Transform raw Biomass into high-density, stable, commodity feedstocks:

- 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



11-50132_3



Biorefinery Scale >800Ktons/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)

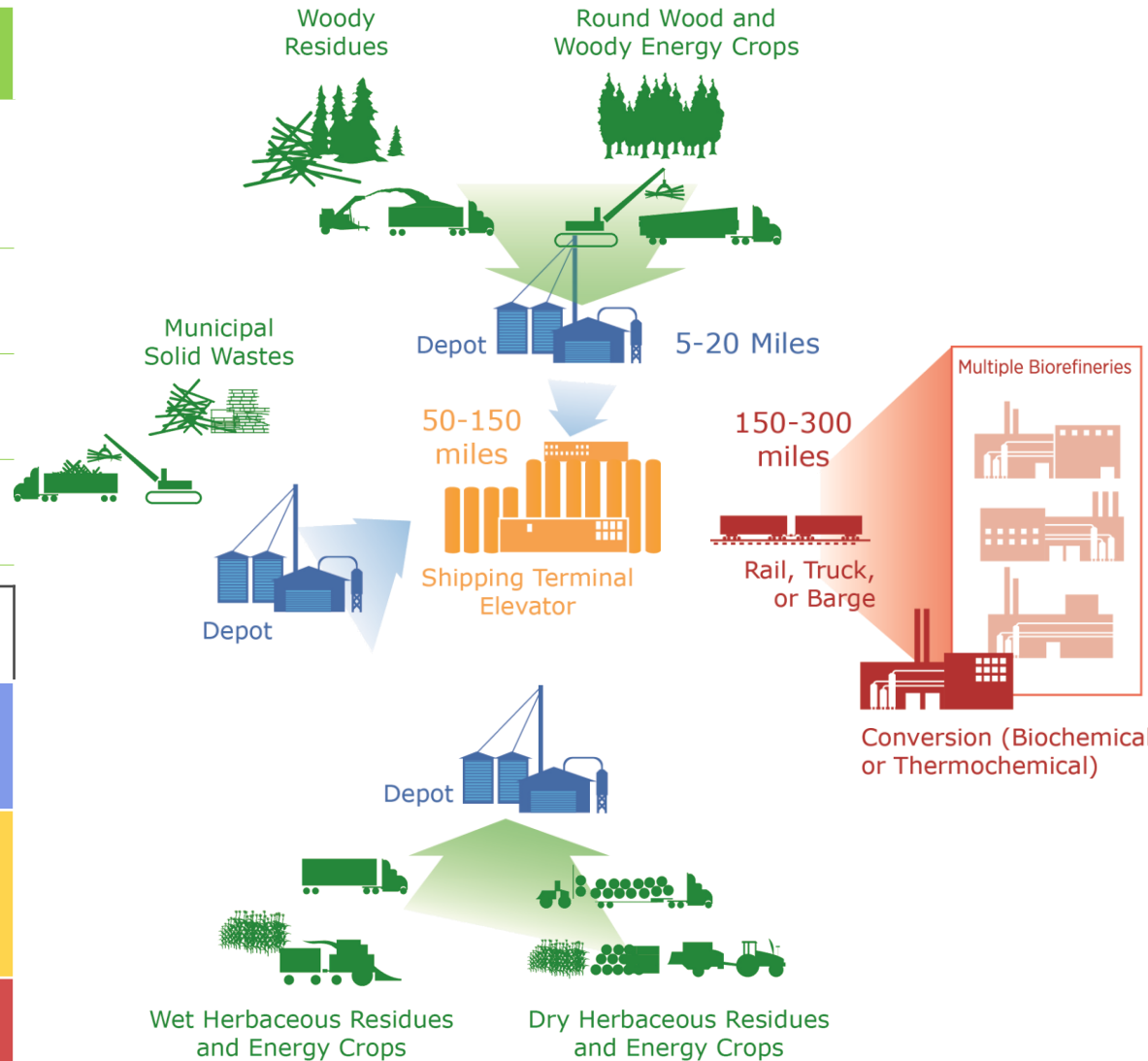
Production to Preprocessing Depot
(5 to 20-mile radius)
Field trucks

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)

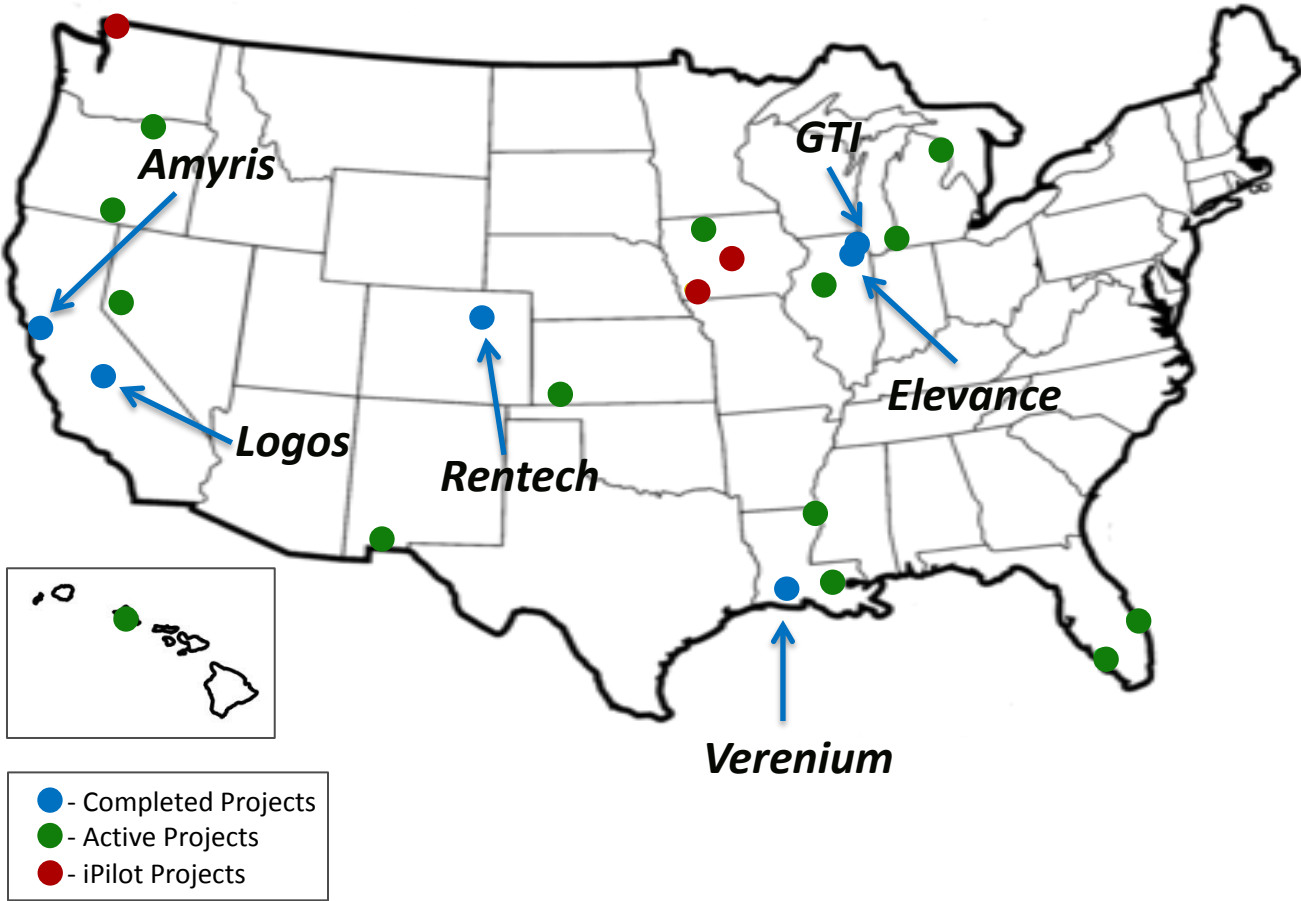
Trans/intercontinental shipping systems (e.g., unit trains, ocean barges, and freightliners)



Demonstration Portfolio – Overview

Map of Active and Completed BETO-funded Projects

- ❑ The Demonstration & Market Transformation (DMT) Program manages a diverse portfolio of projects focused on the scale-up of advanced biofuel production technologies from pilot- to demonstration- to pioneer-scale.
- ❑ Currently, 18 biorefineries are considered active and utilize a broad spectrum of feedstocks and conversion techniques.



For more information visit:
www.energy.gov/eere/bioenergy/integrated-biorefineries

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.








Defense Production Act (DPA) Initiative

In 2011, DOE, USDA, and the Navy signed an MOU for \$510 M to build commercial-scale biorefineries to produce:

- Cost-competitive (w/o subsidies)
- Drop-in fuels for military applications
- From non-food biomass feedstocks



In September 2014, 3 projects were selected:

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

Bioenergy Technologies Office Incubator Selections

Today, DOE is announcing up to \$10 million for seven projects to support innovative technologies that are not represented in a significant way in the Bioenergy Technology 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.

FY15 Funding Opportunities and Awards

Upcoming Award Announcements

- **Targeted Algal Biofuels and Bioproducts FOA**
 - The FOA seeks to reduce the cost of algal biofuels from \$7 per gallon – the current projected state of technology for 2019 – to less than \$5 per gallon algal biofuel by 2019.
 - **STATUS:** Awards anticipated June 2015
- **Landscape Design for Sustainable Bioenergy Systems FOA**
 - DOE announced up to \$14 million to support landscape design approaches that enhance the environmental and socio-economic sustainability of cellulosic bioenergy through the improvement of feedstock production and logistics systems.
 - **STATUS:** Awards anticipated April 2015

Potential Funding Opportunities

- USDA/DOE Biomass Research and Development Initiation (BRDI)
- Manufacturing Biofuels at Increasing Scale
- Fuel Testing and Engine Development for High Octane Fuels
- 2015 BETO Incubator

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.

Upcoming Events

2015 Peer Review

- March 23-27, 2015 at the Hilton Mark Center in Alexandria, VA.
- A combined 1-week simultaneous biennial review of BETO funded projects.

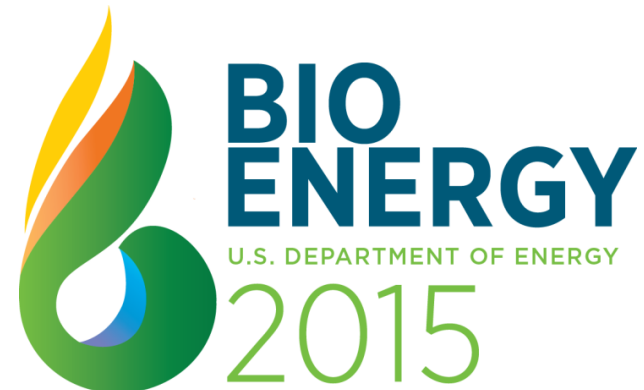
<http://www.energy.gov/eere/bioenergy/2015-project-peer-review>

Bioenergy 2015

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

2015 PROJECT
PEER REVIEW

U.S. DEPARTMENT OF ENERGY
BIOENERGY TECHNOLOGIES OFFICE



Appendix