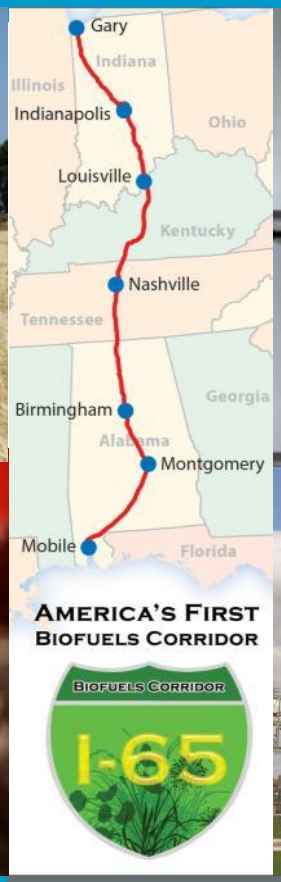
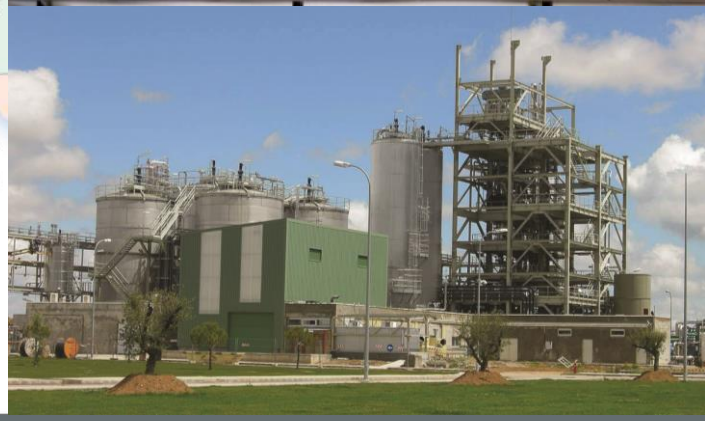




Biomass R&D Technical Advisory Committee (TAC)

March 31, 2017

Jonathan Male

Director

Contents

From Challenge to Opportunity

THE CHALLENGE

More than $350 million is spent **every day** on foreign oil **imports**. Dependence on **foreign oil** can leave us vulnerable to disruptions in supplies and contributes significantly to our trade deficit.

Transportation accounts for 67% of petroleum consumption and 26% of emissions in the United States.

THE OPPORTUNITY

More than **1 billion tons of biomass** could be domestically converted into biofuels and products.

Biomass could displace **25%** of U.S. petroleum use annually by 2030, **keeping $260 billion in the United States**, adding **1.1 million direct jobs,** and reducing annual CO_2 emissions by 450 million tons or 7% of U.S. energy emissions.

BETO's Mission & Vision

Vision: A thriving and sustainable bioeconomy fueled by innovative technologies

Mission: Developing and demonstrating transformative and revolutionary sustainable bioenergy technologies for a prosperous nation

Strategic Goals: Develop industrially relevant technologies to enable domestically produced biofuels and bioproducts without subsidies

BETO reduces risks and costs to commercialization through RD&D.

Bioenergy Delivers Unique Value

- **Biomass** is an energy resource **derived from non-food** plant-, algal-, and waste-based materials that includes crop residues (corn stover), purpose-grown grass crops, woody plants, industrial wastes, algae, wood waste, and sorted municipal solid waste.

- Only renewable energy source that offers a **viable substitute** for petroleum-based liquid transportation **fuels** in the near term and can be used to produce **chemicals** for manufacturing, as well as supply **power** for our electrical grid.

- Can contribute to a more secure, sustainable, and economically sound future by providing **domestic** clean **energy** sources, **reducing** U.S. dependence on **foreign oil**, generating **U.S. jobs**, and revitalizing **rural and urban America**.

- BETO is focused on developing cost-competitive bioenergy technologies to enable the United States to emerge as the **global leader in the clean energy economy**.




America's biomass resources could provide domestic energy, revenue, and jobs.

BETO Impacts

Since 2009 …

Lab Patents

246

Lab Publications

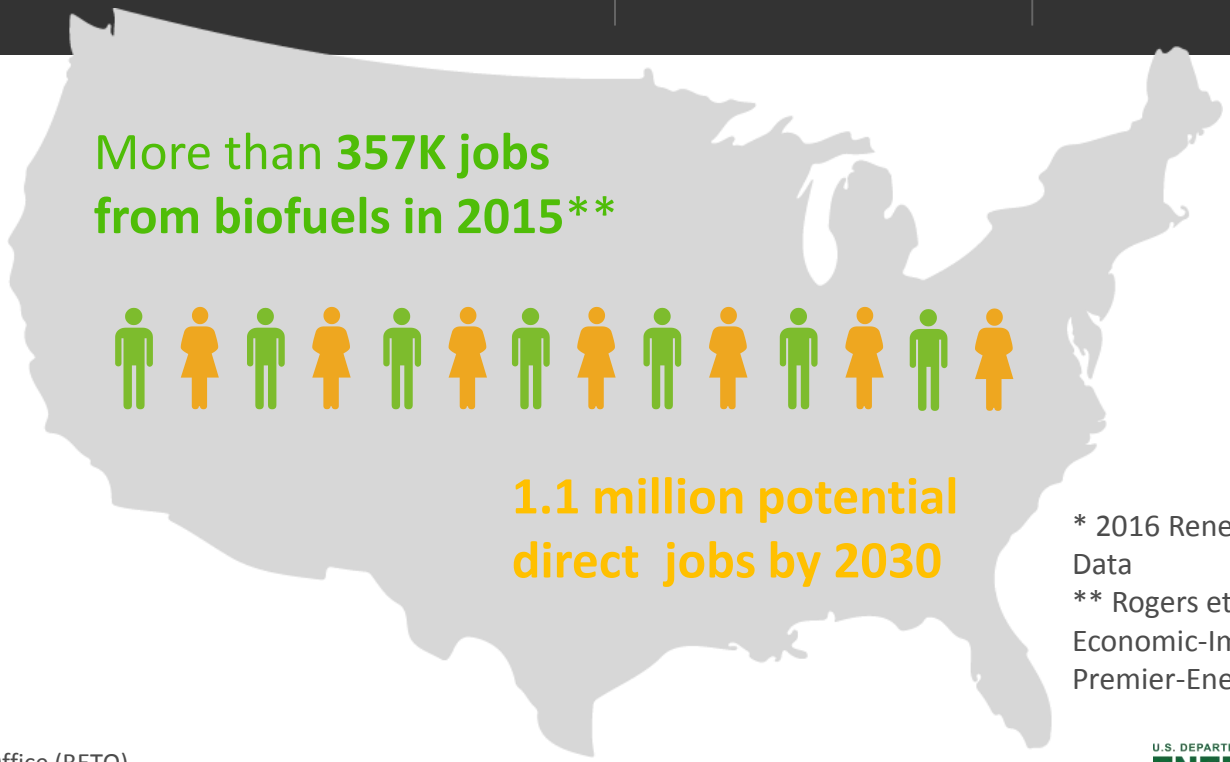
916

Lab Licenses

32

Biofuel Production

3,837,918* Gallons of Cellulosic Biofuel



* 2016 Renewable Fuel Standard Data

** Rogers et al. 2016, Ethanol-Economic-Impact-for-2015, & RFS-Premier-Energy-Program-2016

FY17 Budget Request to Congress

Program Area	FY 2015 Enacted*	FY 2016 Enacted*	FY 2017 Senate Mark*	FY 2017 House Mark*
Conversion Technologies	95,800	85,500	98,971	64,371
Demonstration and Market Transformation	79,700	75,100	60,000	45,000
Analysis and Sustainability	11,000	11,000	10,229	10,229
Advanced Algal Systems	25,000	30,000	30,000	30,000
Feedstocks Supply and Logistics	7,000	16,500	12,000	12,000
NREL Site-Wide Facility Support	6,500	6,900		
Total, Bioenergy Technologies	225,000	225,000	218,100	168,500

*Dollars in thousands

Feedstock Supply & Logistics: Major Goals FY17 – FY22

Supply By 2017, establish available resource volumes for non-woody municipal solid waste (MSW) and algal feedstocks at $84/dry ton

Supply By 2018, establish nationwide sub-county-level environmental impact criteria and logistics strategies for all potential energy crops

Logistics By 2017, verify an average annual sustainable delivered feedstock cost of $84/dry ton at the conversion reactor throat (including grower payment and logistics cost)

Logistics By 2022, validate one blendstock for thermochemical conversion and one blendstock for biochemical conversion at a scale of 10 tons per day, while also meeting the $84/dry ton delivered cost target




Advanced Algal Systems: Major Goals FY17-22

Sustainability

By 2017,

model the sustainable supply of 1 million metric tonnes cultivated algal biomass

Value

By 2019,

demonstrate production of valuable co-products that can increase the value of cultivated algal biomass by 30%

Yield

By 2020,

demonstrate, at non-integrated pre-pilot scale, yield of 3,700 gallons or equivalent algal biofuel intermediate per acre, annual average

Cost

By 2022,

demonstrate yield of 5,000 gallons of algal biofuel intermediate in support of modelled $3 per gallon (gasoline equivalent) algal biofuels

Conversion R&D: Major Goals FY17-22

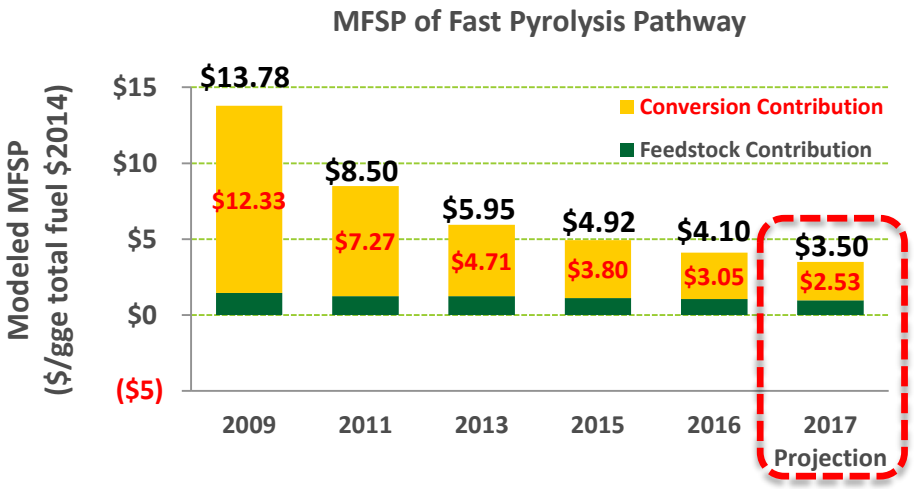
By 2017, validate at least one pathway with a **$3/GGE (2014$)** hydrocarbon biofuel* minimum fuel selling price (MFSP)

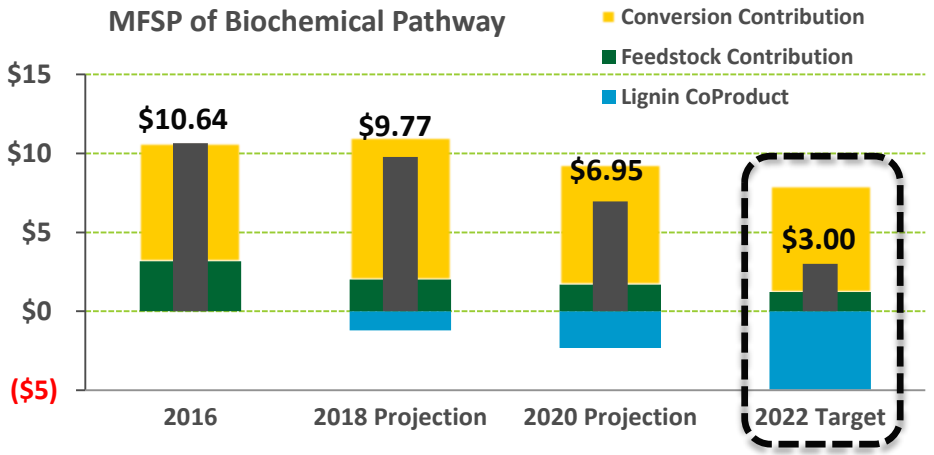
By 2018, select an integrated bench-scale lignin upgrading strategy for valorization of lignin in a hydrocarbon fuel production process

By 2020, provide enabling capabilities in synthetic biology that reduces Design-Built-Test-Learn cycles and time-to-scale by at least 50% compared to the current average of ~10 years.

By 2021, complete the R&D necessary for a 2022 verification that produces both fuels and high-value chemicals to enable a biorefinery to achieve a positive ROI

By 2022, validate an nth plant modeled cost of at most **$3/GGE for a total of 3 pathways** to hydrocarbon biofuels*





*with GHG emissions reduction of >50% compared to petroleum-derived fuel

Demonstration and Market Transformation

Strategic Goal: *Develop commercially viable biomass utilization technologies and supporting **infrastructure** to enable **domestic resources** to capitalize on **biomass-to-bioenergy value chain**.*

Approaches:

- Foster public-private partnerships to enable the deployment of technologies, from the R&D stages to the marketplace
- Validate performance at pilot-, demonstration-, and pioneer-scale integrated biorefineries to de-risk technologies and enable financing
- Identify new market opportunities and address market barriers related to infrastructure and end use.

Increasing market opportunities and demand for end products

Current Consortia

Consortium for Computational Physics and Chemistry

Chemical Catalysis for Bioenergy - ChemCatBio

Separations Consortium

Agile BioFoundry
(ABF)

Feedstock-Conversion Interface

Examples of BETO-Enabled Commercial Products

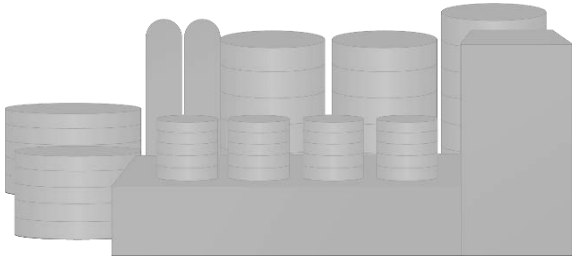
Products

- Virent Inc. developed a process to convert biomass to a material used to produce containers for liquids.
- Coca-Cola licensed this technology for its PlantBottle™ packaging.

Technologies

- The State University of New York and Case New Holland, produced a single-pass harvester for shrub willow.
- Fort Drum, an Army base located in upstate New York and run by a 60-megawatt biomass power plant is partially fueled by the shrub willow harvested by the local farmers using this technology.

Fuels



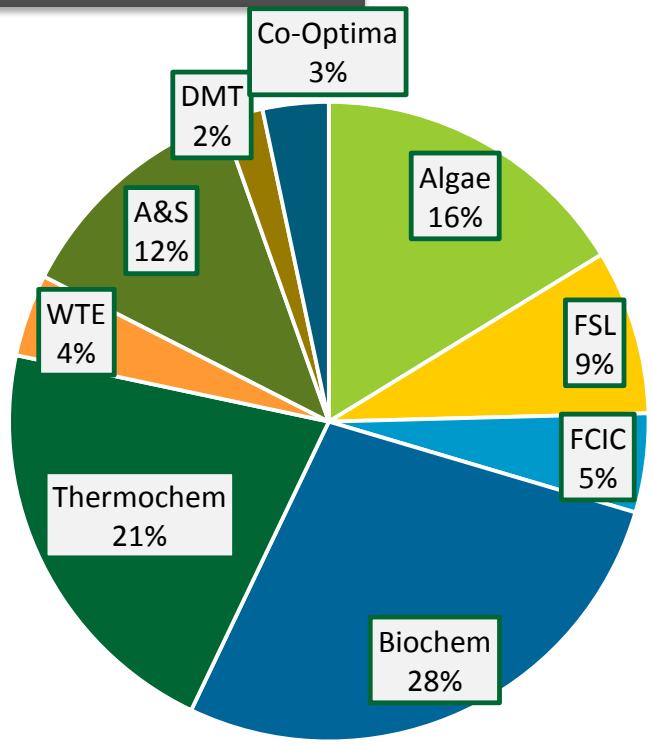
- POET DSM's commercial-scale cellulosic ethanol plant in Emmetsburg Iowa named "Project LIBERTY" is capable of producing 25 million gallons per year at full capacity.
- Made possible by DOE cost-shared support for the development, design, and construction of this pioneer facility.

Providing domestic manufacturing jobs & increased economic opportunity in rural areas

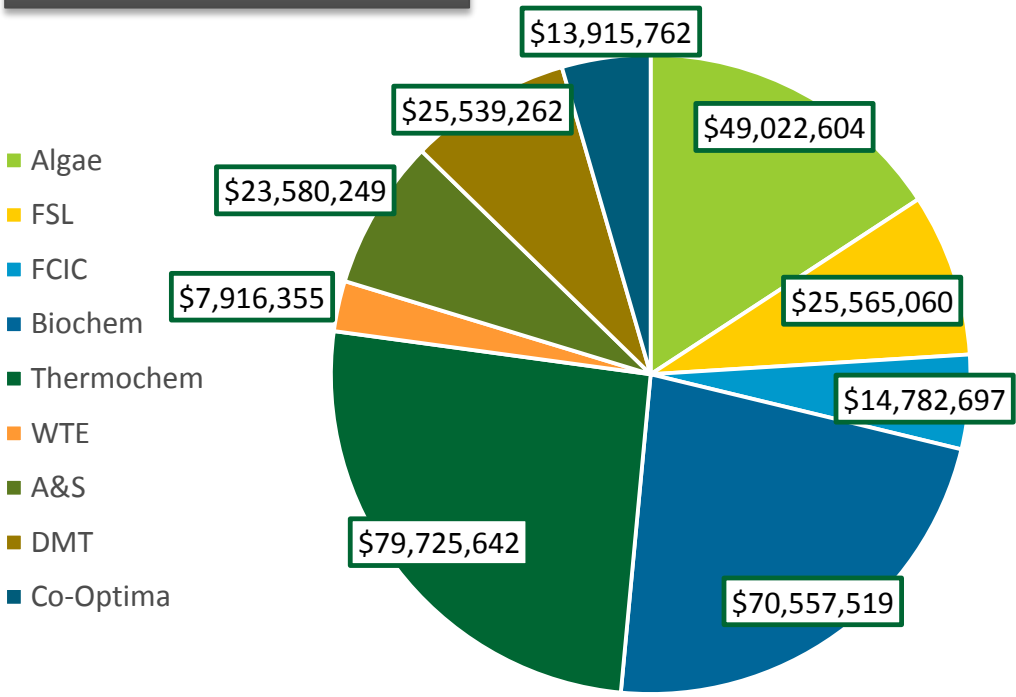
2017 Peer Review

The 2017 Project Peer Review covered 277 projects (182 presentations) across 5 technology areas, representing a combined value (FY15-17) of ~$300 M.

By # of Projects



By Project Funding



BETO-Driven Market Opportunities

Small Business Vouchers Pilot
U.S. DEPARTMENT OF ENERGY

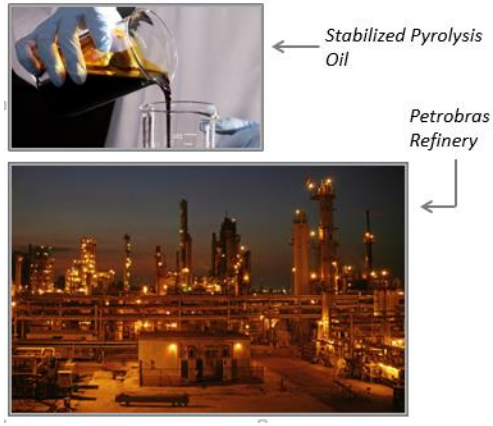
Supporting Domestic Small Business Innovation - The SBV Pilot supports small businesses to bring new clean energy technologies to market faster by giving them access to state-of-the-art facilities and capabilities.

Transforming "waste streams" into revenues for rural economies - BETO-funded projects have transformed industrial waste gases into jet fuels, as well as converted sewage sludge into renewable fuel. Both technologies are currently being licensed for commercial applications.

Increasing energy security by providing cost competitive military grade fuels - BETO will continue to implement clean energy solutions through initiatives like the Navy's Great Green Fleet, which aims to bring clean technologies to installations nationwide.

Using untapped resources to enhance energy security and job growth

BETO Technology Approaching the Market

BETO Technology Approaching the Market	R&D + Industry Partnership	Impact
	LanzaTech, Michigan Tech, University of Delaware, Pacific Northwest National Laboratory, Imperium Renewables	• LanzaTech licensed microbial strains to produce alcohol • Neat fuel meets alcohol-to-jet specs and 50% Jet A blend meets ASTM specs • Demonstration fuel will be used in future flight test with Virgin Atlantic to support goal of adding to ASTM D7566, Annex 5
	ENSYN, Petrobras, NREL, Chevron, Southwest Research Institute	• Ensyn produces renewable bio-oil to be co-processed with petroleum sources or to sell for heating • Processing utilizes existing 6 million BBL/day US FCC capacity • Co-processed diesel and gasoline were approved as EPA registered fuels and under LCFS by CARB

Bioenergy Upcoming Workshops & Events

- **Bioeconomy Initiative: Action Plan Coordination Meeting**
  - April 5-6, 2017, Washington, DC
- **Second Annual National Lab Summit**
  - April 18, 2017, Beltsville, MD
- **Bioeconomy 2017 and Program Management Review**
  - July 11-13*, 2017, Pentagon City, VA
    - *Program Management Review: July 13, 2017

Project Partners

BETO works with partners in industry, universities, and the national labs.

Appendices

Co-Optimization of Fuels and Engines Initiative

On December 29th, 2016, the Energy Department announced up to $7 million for eight universities to accelerate the introduction of affordable, scalable, and sustainable high-performance fuels for use in high-efficiency, low-emission engines.

Cornell University	University of Michigan	University of Michigan- Dearborn	University of Alabama
Louisiana State University	Massachusetts Institute of Technology	Yale University	University of Central Florida

Integrated Biorefinery Optimization FOA

Joint FOA with USDA, up to $22.7 million in support of the optimization of IBRs (DE-FOA-0001689) Released January 6, 2017

- DOE share of up to $19.8 million; USDA-NIFA share of up to $2.9 million
- Applications must be focused on lowering technical and financial risk, addressing challenges encountered with the successful scale-up, and reliable, continuous operation of IBRs

Four Topic Areas:

- **Topic Area 1:** Robust, continuous handling of solid materials (dry and wet feedstocks, biosolids, and/or residual solids remaining in the process) and feeding systems to reactors under various operating conditions
- **Topic Area 2:** High value products from waste and/or other under-valued streams in an IBR
- **Topic Area 3:** Industrial separations within an IBR
- **Topic Area 4:** Analytical modeling of solid materials (dry and wet feedstocks, and/or residual solids remaining in the process) and reactor feeding systems

Apply at *https://eere-exchange.energy.gov*

Submission Deadline for Concept Papers	**2/6/2017**
Submission Deadline for Full Applications	**4/3/2017**

Productivity Enhanced Algae and tool-Kits (PEAK)

Up to $8 million in Federal Share funding announced December 15th
(DE-FOA-0001628)

Goals: Achieve an annual average algal biomass productivity of at least 18 g/m^2/day, extrapolated from the combination of relevant seasonal data from the project and literature values for seasonal regimes not targeted by a given project, while achieving a minimum of 80 gasoline gallons equivalent per ton of biomass potential, by 2020.

Approach: Small teams will develop strategies to increase areal productivity AND biofuel yield via enhanced algal strains OR enhanced management of ecological or abiotic contributions to cultivation biology. Teams will also develop improved or novel algal toolkits and/or methods.

Apply at *https://eere-exchange.energy.gov*

Submission Deadline for Concept Papers	**1/13/2017**
Submission Deadline for Full Applications	**2/22/2017**

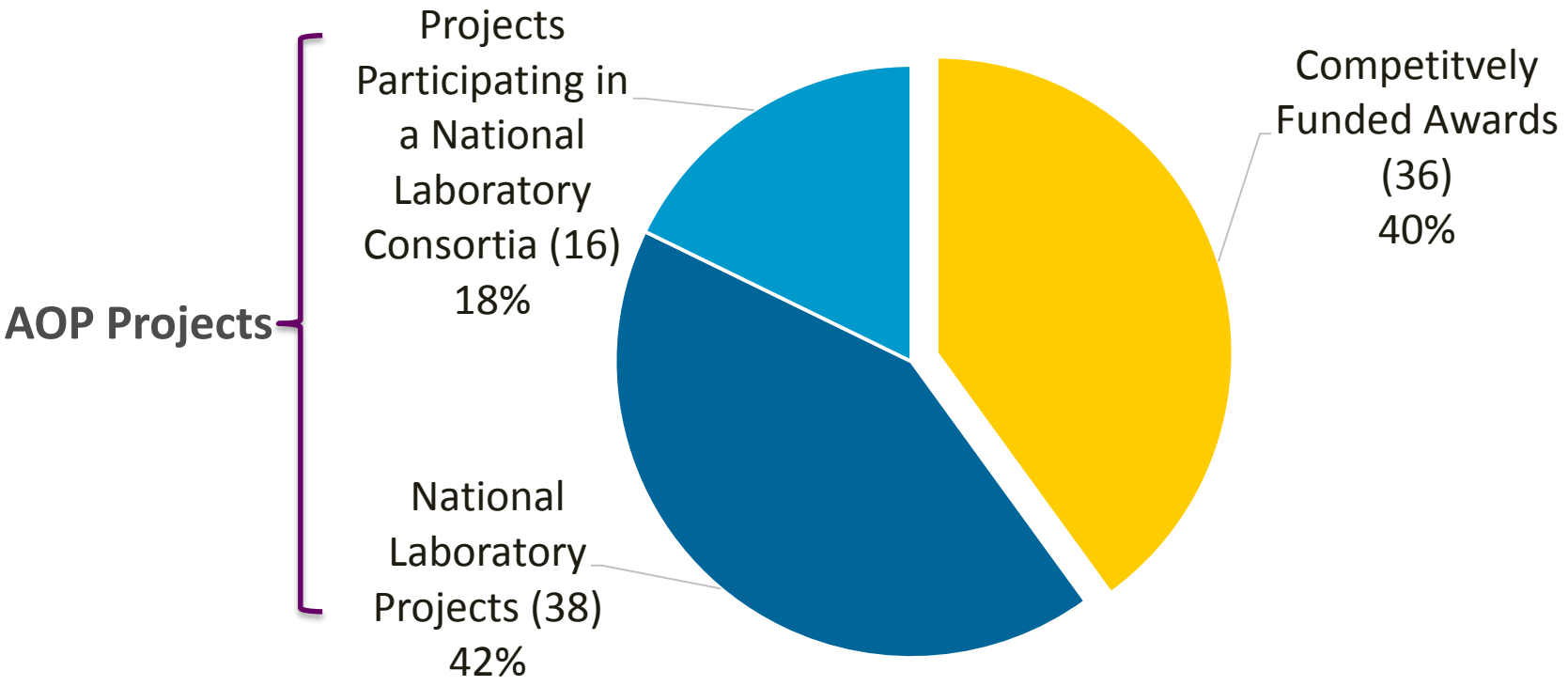
Project Development for Pilot and Demonstration Biofuels and Bio-products Manufacturing (PD2B3)

On December 28th, 2016, DOE announced up to $12.9 million for six projects related to the manufacturing of advanced or cellulosic biofuels, bioproducts, refinery-compatible intermediates, and/or biopower in a domestic pilot- or demonstration-scale integrated biorefinery.

Demonstration-Scale Integrated Biorefineries	**AVAPCO, LLC**
	LanzaTech, Inc.
Pilot-Scale Integrated Biorefineries	**Global Algae Innovations**
	ThermoChem Recovery International, Inc.
Pilot-Scale Waste-to-Energy Projects	**Rialto Bioenergy, LLC**
	Water Environment & Reuse Foundation

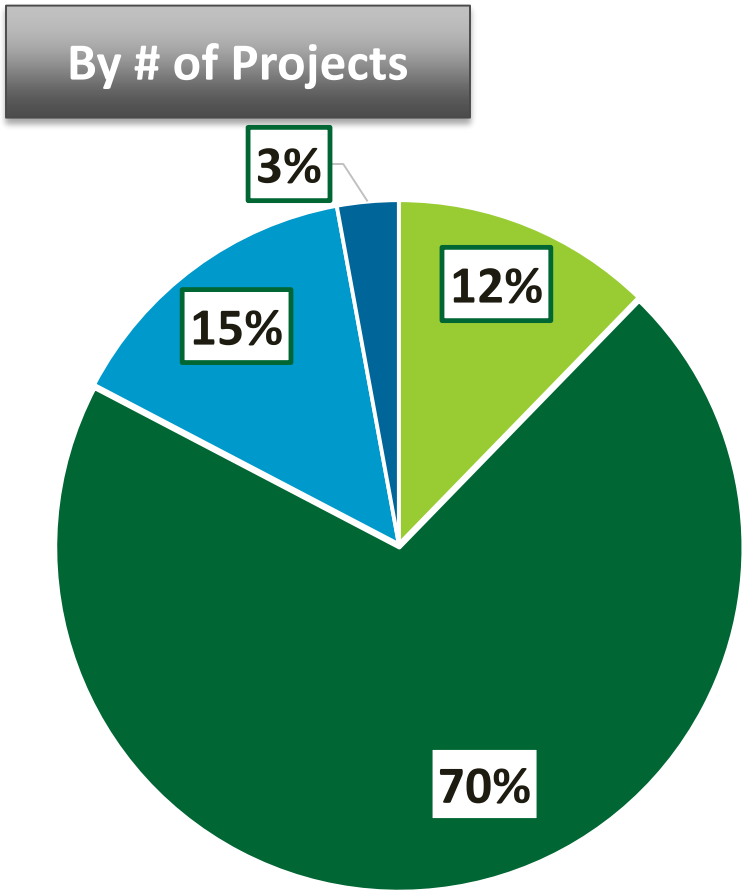
Project Breakdown

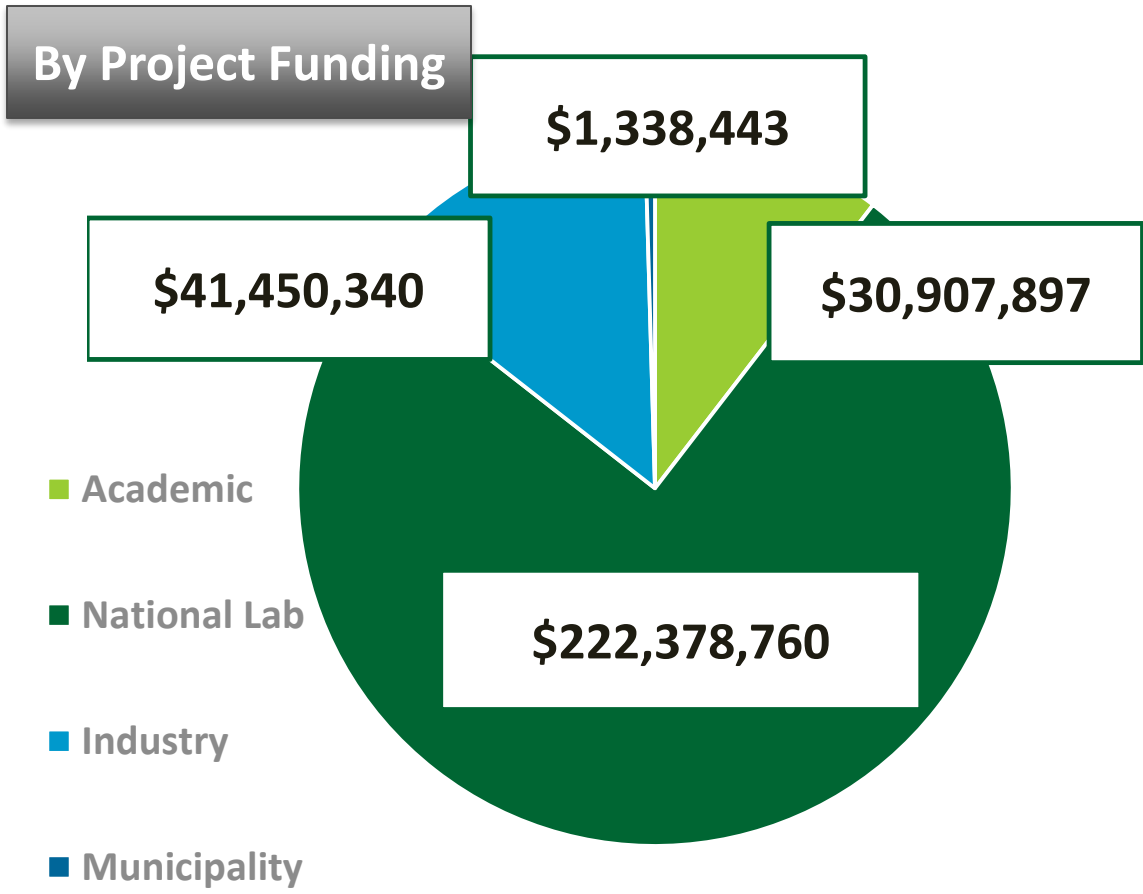
At this review:



Projects by Affiliation of Project Recipient

Lab-directed projects constitute about 70% of BETO Projects and 75% of project funding. These charts reflect the affiliation only of the lead PI; many projects have lab, industry, and university partners.



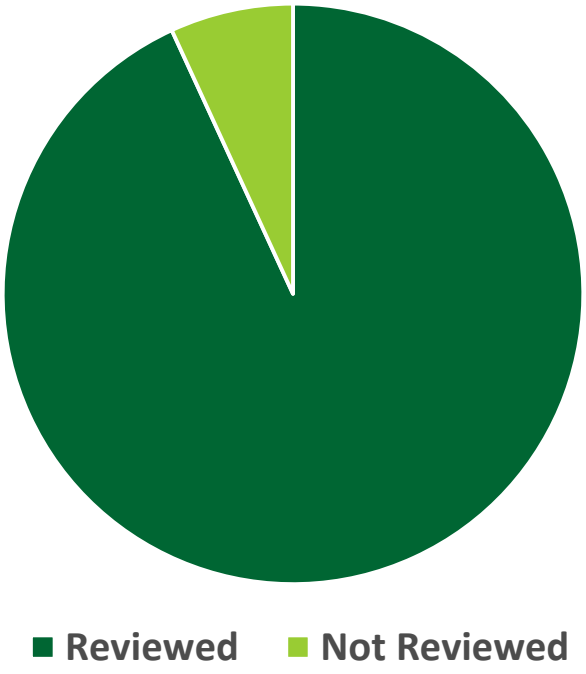


Reviewed Projects as Percentage of the Portfolio

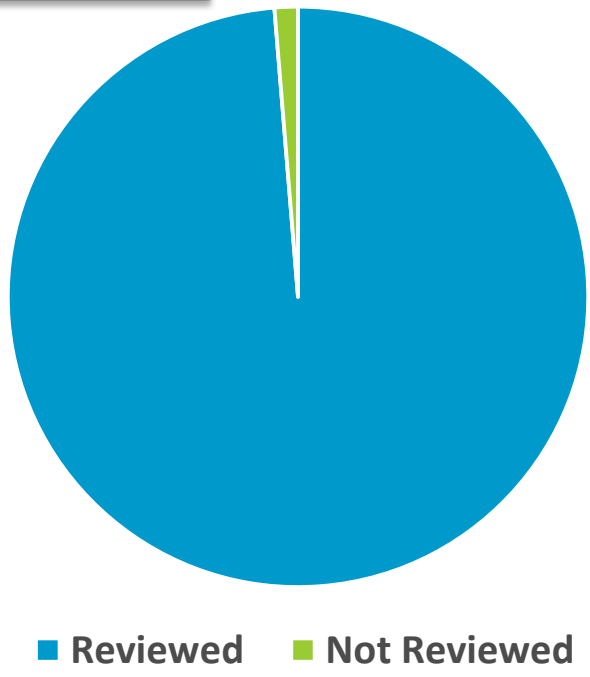
This review will cover 93% of the projects in BETO's portfolio, which represents 99% of project funding.

Project Reviewed		
Yes	258	$292,227,317
No	19	$3,848,122
Total	277	$296,075,439

By # of Projects

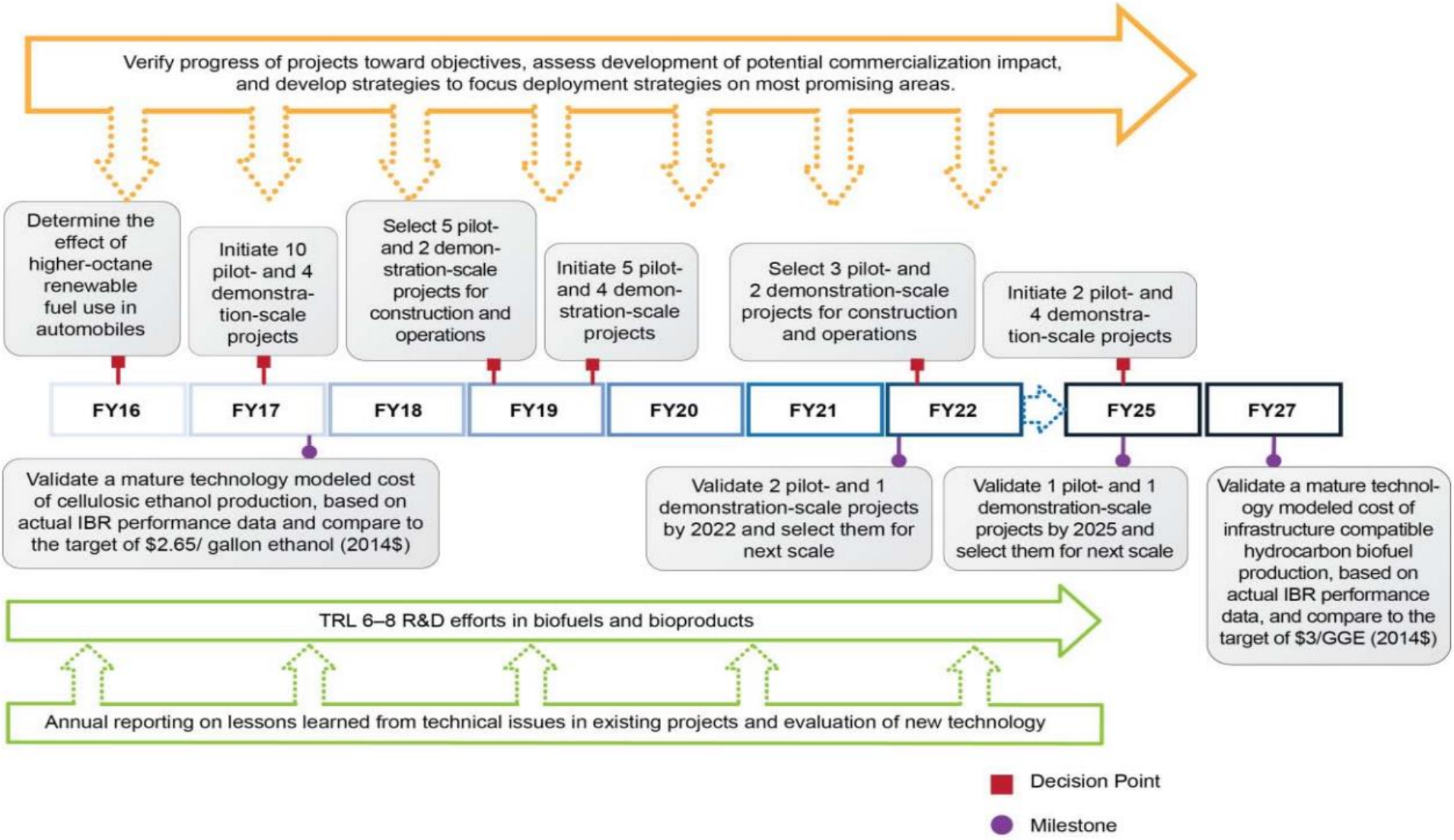


By Project Funding



Demonstration & Market Transformation: Major Goals FY17-22

By 2017, validate a mature technology modeled cost of cellulosic ethanol production, based on actual integrated biorefinery performance data, and compare to the target of $2.65/gallon ethanol (2014$)



BETO Technology in the Market

BETO Technology in the Market	R&D + Industry Partnership	Impact
Self-propelled woody crop harvester  	ESF State University of New York College of Environmental Science and Forestry CNH	• Case New Holland commercialized their system, which doubled output while cutting costs by 33% • Fort Drum Army base in NY is run by a 60-megawatt biomass power plant, partially fueled by woody biomass harvested with this technology
 Coca-Cola PlantBottle  Fuel Blend Stock	VIRENT NABC National Advanced Biofuels Consortium INL Idaho National Laboratory TESORO Coca-Cola	• Virent produces bio-intermediates for fuels and products • Tesoro acquired Virent and plans to scale-up • Coca-Cola and Virent plan to produce 100% PlantBottles by 2020 (35 billion bottles)