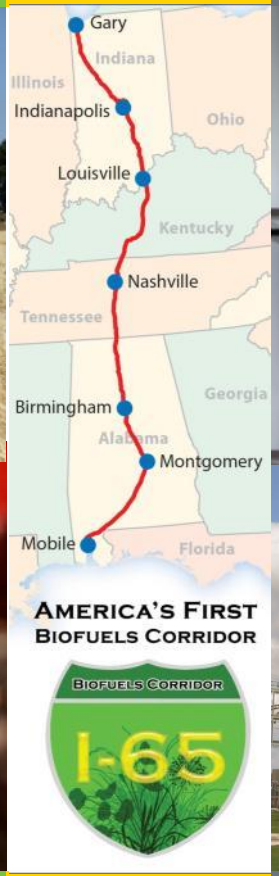
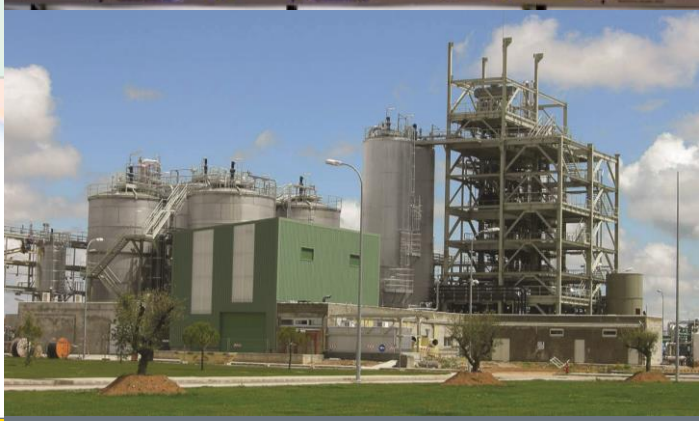
Bioenergy Technologies Office

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





2015 BETO Project Peer Review – Conversion Area Overview

Bryna Guriel, Technology Manager

Conversion R&D

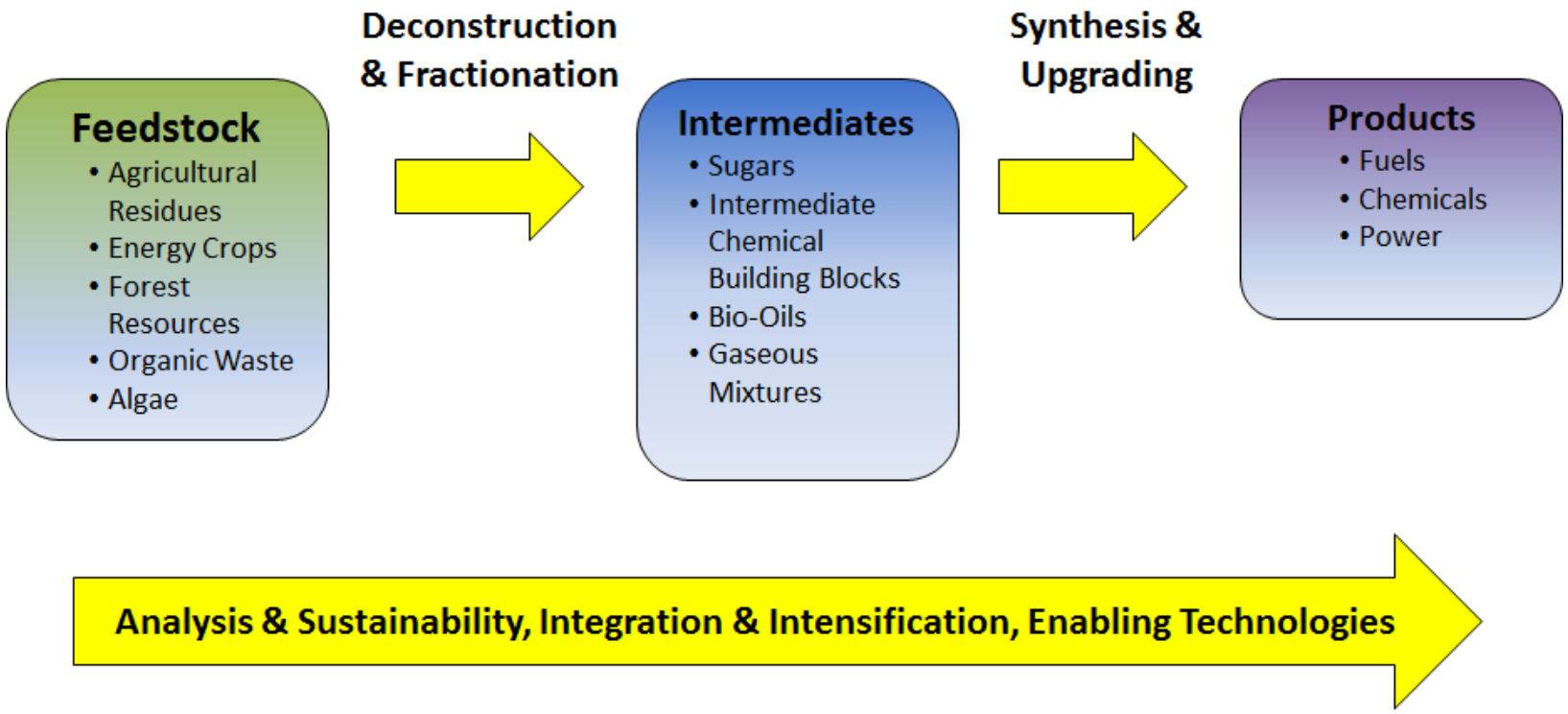
March 23rd 2015

Introduction to Conversion R&D

FY15 Program Overview

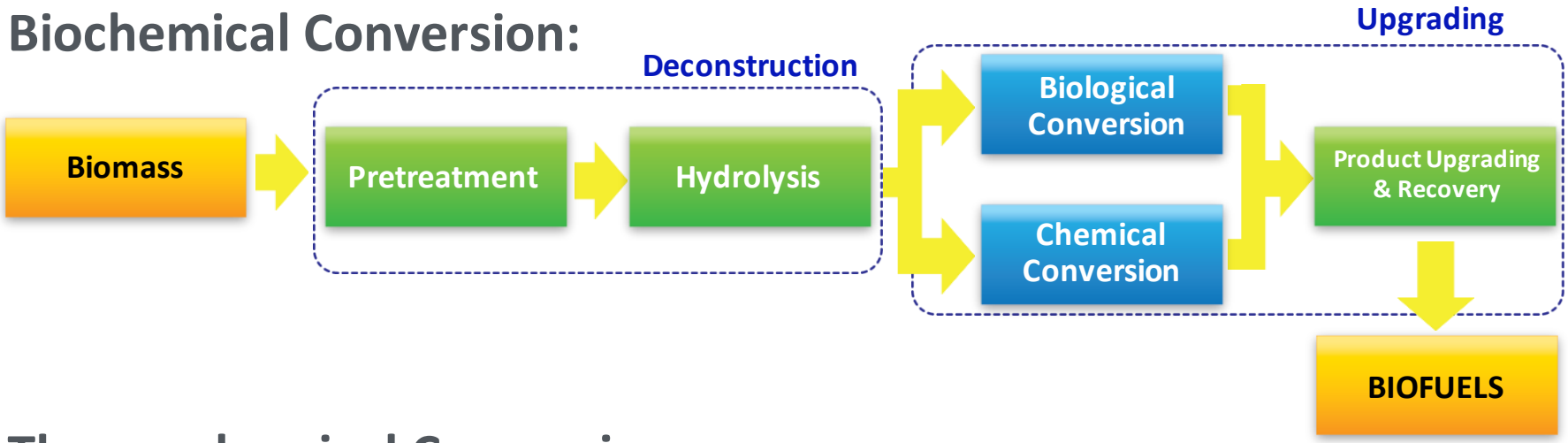
- The strategic goal of the conversion program is to *develop **commercially viable** technologies for converting feedstocks via biological and chemical routes energy-dense, fungible, finished liquid fuels, such as renewable gasoline, jet, and diesel, as well as biochemicals and biopower.* This corresponds to the following cost targets:
  - By **2017**, validate an nth plant modeled MFSP of $3/GGE (in 2011 dollars) via **a conversion pathway** to hydrocarbon biofuel with **GHG emissions reduction of 50 percent** or more compared to petroleum-derived fuel.
  - By **2022**, validate an nth plant modeled MFSP of $3/ GGE (in 2011 dollars) for **two additional conversion pathways** to hydrocarbon biofuel with **GHG emissions reduction of 50 percent** or more compared to petroleum-derived fuel.

Role of Conversion R&D Within the Office

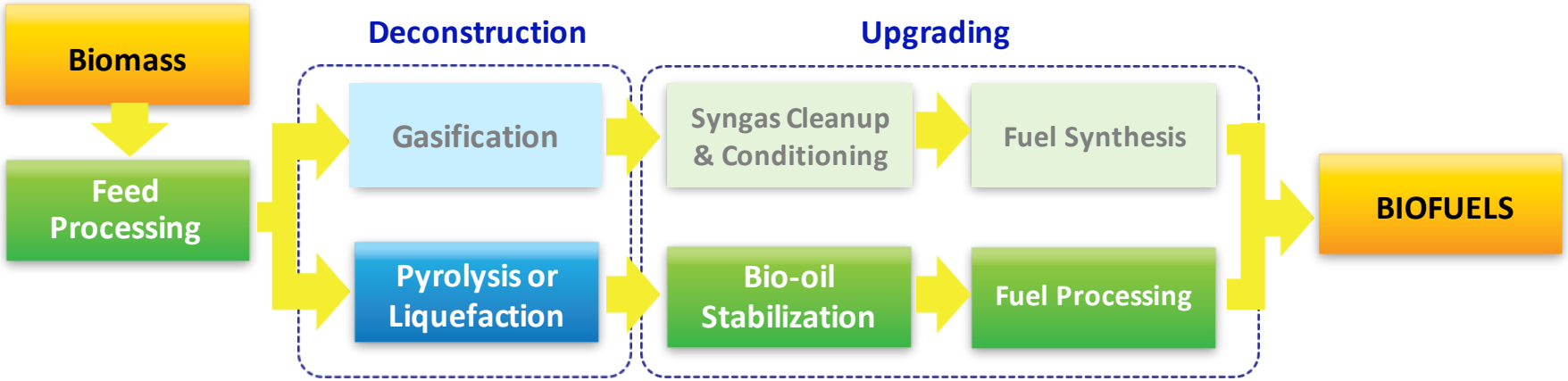


"Old" Pathways

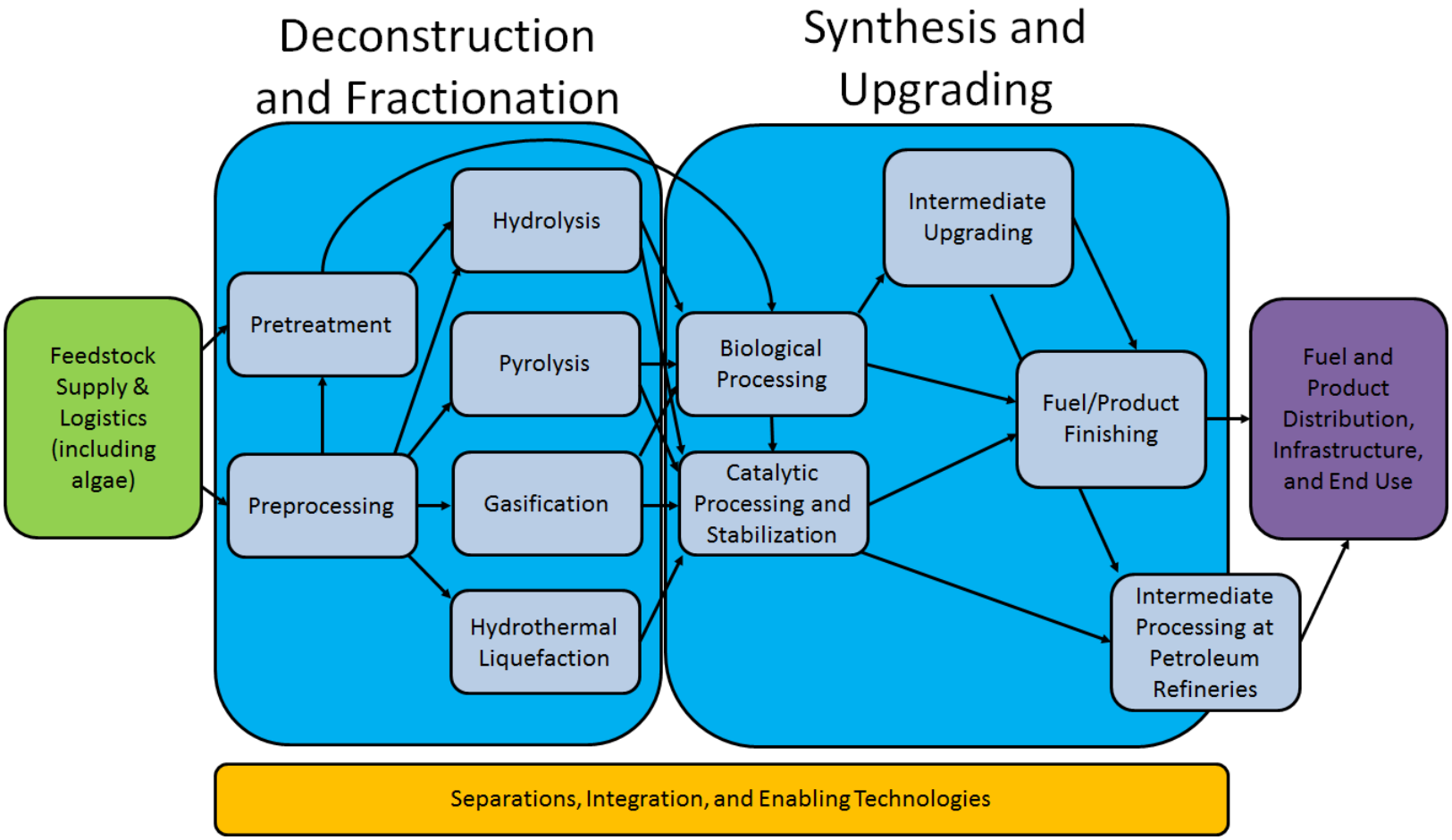
Biochemical Conversion:



Thermochemical Conversion:



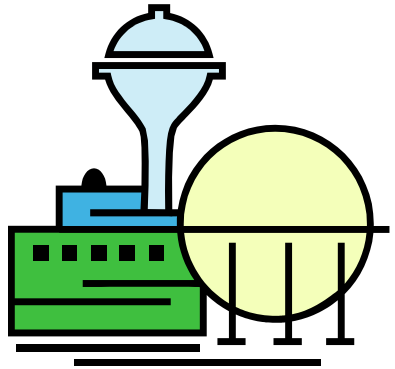
New Pathways



Path to a Bioeconomy

R&D

D&D (DMT) + Industry



Bio-industry

- Challenges
  - How do we do validation in the future?
  - Where/how does hand-off take place?
  - How do we track our R&D progress in terms that make sense to the Congress and the public?

FY15 Program Overview

The Office is pursuing design case models detailing six pathways that exemplify how the conversion platform is progressing toward these cost targets for biofuels. Each design case includes:

- Conversion cost projections and technical targets
- Environmental sustainability metrics.

Conversion Area	Pathway
Biochemical	Low-Temperature Deconstruction and Fermentation
Biochemical	Low-Temperature Deconstruction and Catalytic Sugar Upgrading
Thermochemical	Fast Pyrolysis
Thermochemical	In-Situ Pyrolysis
Thermochemical	Ex-Situ Pyrolysis
Thermochemical	Conversion to High Octane Fuels with Gasification

Transition to new WBS numbers for FY15

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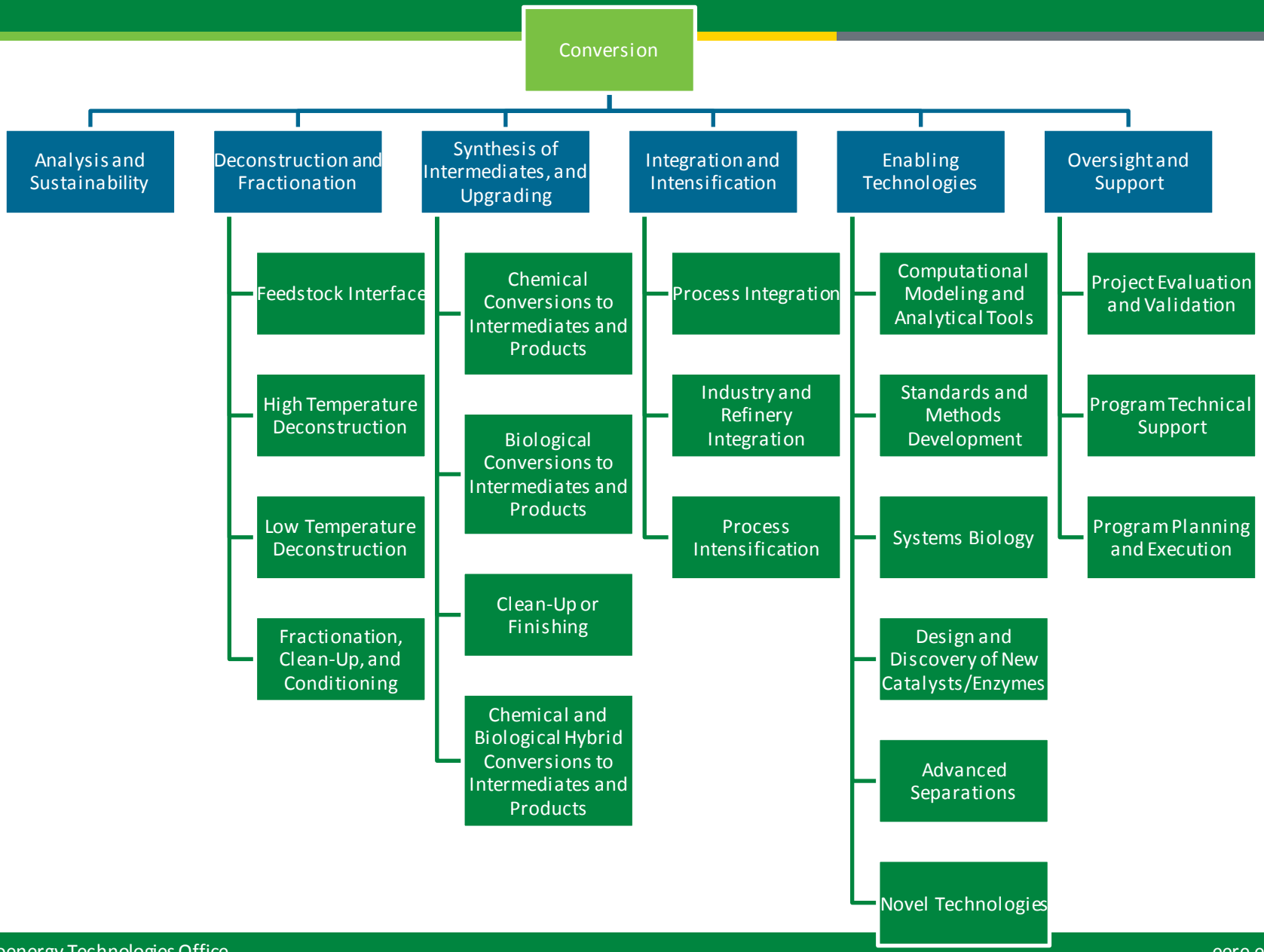
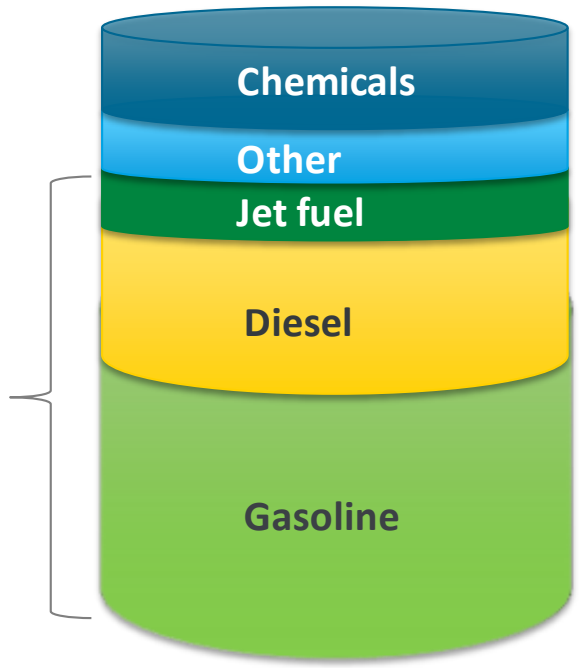


Petroleum products in the US: the breakdown of a barrel of oil



Chemicals make up **16%** of the volume of US oil products and are worth **$812B**

Fuel makes up **76%** of the volume of US oil products and are worth **$935B**

The US produces 15% of global chemicals and chemicals comprise 12% of all US exports.

The US produces: ehthylene, propylene, polyethylene, butadiene, butanol, polystyrene, EO, MEG

These chemicals can be converted to: plastics, cosmetics, pharmaceuticals, detergents, packaging, clothing, or car parts.

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

Current Research

Pathway	Description	Key Challenges & Barriers
Biological conversion of sugars*	Production of sugars or biomass via enzymatic or non-enzymatic routes and subsequent biological processing to yield hydrocarbon fuel precursors (e.g. fatty acids, isoprenoids, etc.)	• Biomass variability • Biomass recalcitrance • Biomass fractionation • Lower costs/improve quality of intermediates • Pretreatment processing and costs • Cellulase enzyme production, loading and costs • Enable high performance separations technologies • Improve catalyst performance – cleanup/conditioning & fuel synthesis • Biochemical conversion process integration • Biochemical/thermochemical interface • Maximize carbon utilization • Optimize reactor performance
Chemical conversion of sugars*	Production of sugars or biomass carbohydrate derivates via enzymatic or non-enzymatic routes, and subsequent upgrading of the product stream through catalysis to yield a mix of hydrocarbons suitable for blending.	
Catalytic upgrading of alcohols	Production of sugars via enzymatic hydrolysis followed by fermentation to ethanol, and catalytic upgrading of ethanol to paraffins.	

***Denotes that sugars actually refers to sugars or other lignocellulosic derivatives such as carbohydrate derivatives and lignin**

Current Research

Pathway	Description	Key Challenges & Barriers
Fast Pyrolysis (FP) with Liquid Phase Upgrading	FP followed by a separate liquid phase upgrading step, then multi-stage hydrotreating	• Feeding wet and dry biomass • Catalyst and catalytic process comprehension • Hydroprocessing and hydrogen considerations • Separation systems and selective fractionation • Sensors and controls • Liquefaction of biomass and bio-oil stabilization • Fuel synthesis and upgrading • Utilizing Organics in Waste Streams (Aqueous Phase and Off Gases) • Bio-oil pathway process integration • Refinery Integration
FP with Ex-Situ Vapor Phase Upgrading	FP followed by a separate vapor phase upgrading step, then one or two stages of hydrotreating	
FP with In-Situ Vapor Phase Upgrading	FP in the same reactor as upgrading catalyst, followed by one or two stages of hydrotreating	
Hydrothermal Liquefaction (HTL) or Solvent Liquefaction (SL)	Direct liquefaction in water (HTL) or solvent medium (SL), followed by catalytic upgrading. Used with high moisture feedstocks, such as algae	
Hydropyrolysis	FP in the presence of hydrogen and catalysts, followed by one stage of hydrotreating	

Current Research

Pathway	Description	Key Challenges & Barriers
Syngas Upgrading to Hydrocarbon Fuels Technology Pathway	Upgrading of biomass derived synthesis gas ('syngas') to hydrocarbon fuels. While this specific discussion focuses on the conversion of syngas via a methanol intermediate to hydrocarbon blendstocks, there are a number of alternative conversion routes for production of hydrocarbons through a wide array of intermediates from syngas.	• Feeding wet and dry biomass • Fuel synthesis and upgrading • Sensors and controls • Gaseous intermediates process integration

Budget: Full Conversion R&D (numbers after rescission)

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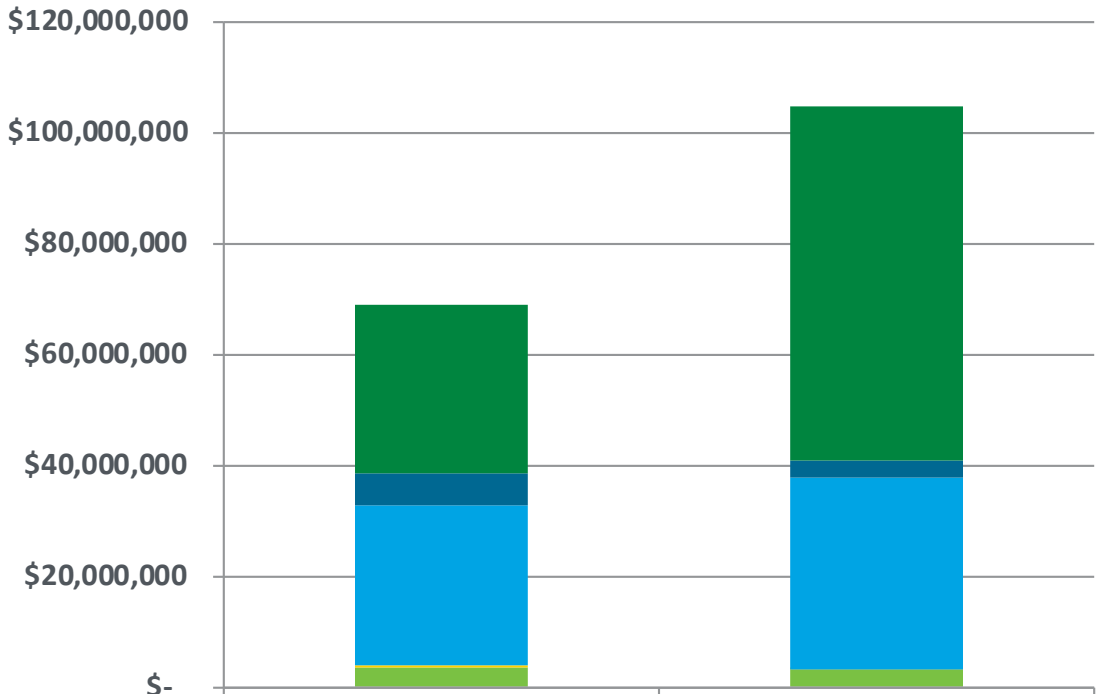


	FY13	FY14
Lab Core R&D	$30,473,906	$63,965,468
Analysis	$5,756,000	$3,280,500
Competitively Selected Projects and CRD	$29,131,814	$34,615,349
International	$281,700	$40,000
Administrative	$3,495,524	$3,004,081.00

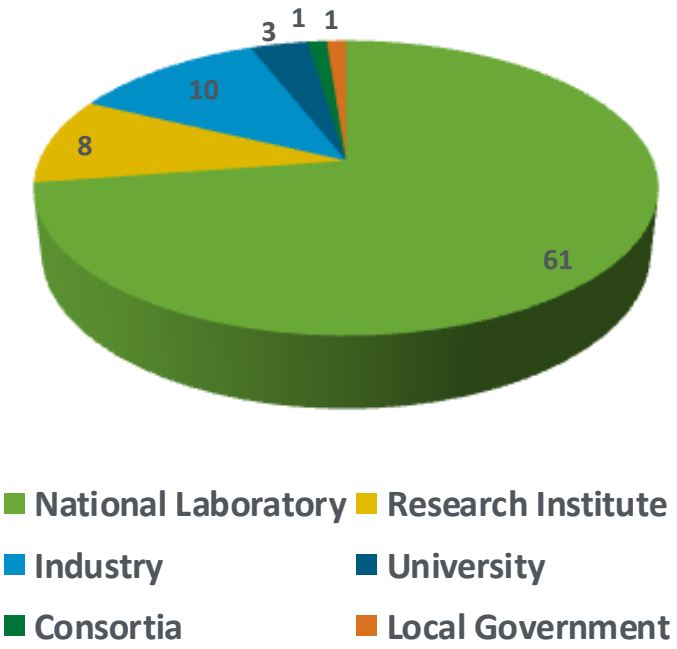
Conversion Project Portfolio

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

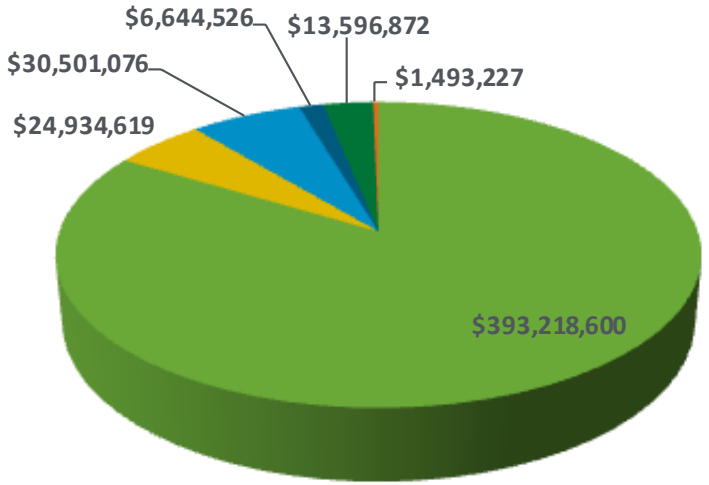
The Biochemical Technology Area will be reviewing 40 projects this week

The Thermochemical Technology Area will be reviewing 44 projects this week

Conversion Performers to be Reviewed



Lifetime Budget of Projects Reviewed



Key Accomplishments in FY13 and FY14

National Renewable Energy Lab

- Developed bench-scale biological "funneling" process to reduce complexity of lignin deconstruction products which facilitates production of value-added co-products in support of 2022 cost goal of $3/gge for HC fuels via biological routes.
- Monitored the deactivation of pyrolysis upgrading catalysts in real time to determine operating ranges for catalytic upgrading of pyrolysis vapors.
  - Research is being used to establish baseline operating conditions for the larger scale DCR and TCPDU reactors, and identifying mechanisms of deactivation that are being used by Johnston Matthey.
  - Conditions were identified that reduce coke by 30% leading to a potential cost reduction of $0.60 for the *ex situ* pathway due to increase product yields.

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Pacific Northwest National Laboratory

- Demonstrated the integrated production of a very high quality jet fuel from low-cost ethanol produced directly from industrial waste gasses that meet a GHG reduction exceeding 60%.
  - Liter quantities of the fuel analyzed by the Air Force Research Laboratories and shared with Boeing and GE;
  - the BETO-funded process has now been added to ASTM approval process for alcohol to jet fuel.

Lawrence Berkeley National Laboratory

- ABPDU staff (LBNL) collaborated with Lygos, GreenLight Biosciences, Kiverdi, and Microvi as well as large corporations such as TOTAL and FATER, a Procter & Gamble subsidiary, to overcome development and scaling issues.

BERKELEY LAB

ABPDU
Advanced Biofuels Process Demonstration Unit

Key Accomplishments

Argonne National Laboratory

- Won a Federal Laboratory Consortium award for Excellence in Technology Transfer (With ADM and Nalco) for its resin wafer electrodeionization technology (RW-EDI) (2012) which is approximately 15-30% less expensive than solvent extraction for removal of organic acids from water

Argonne NATIONAL LABORATORY

Oak Ridge National Laboratory

- Developed promising ethanol upgrading catalyst technology for hydrocarbon fuel blendstocks and successfully transferred the technology to the private sector for scale up and commercialization
- Invented novel membrane technology which received an R&D-100 award in 2014 and successfully applied the technology to small scale bio-oil processing with NREL

OAK RIDGE National Laboratory

Key Accomplishments

Design Reports

(ANL, INL, NREL, ORNL, PNNL)

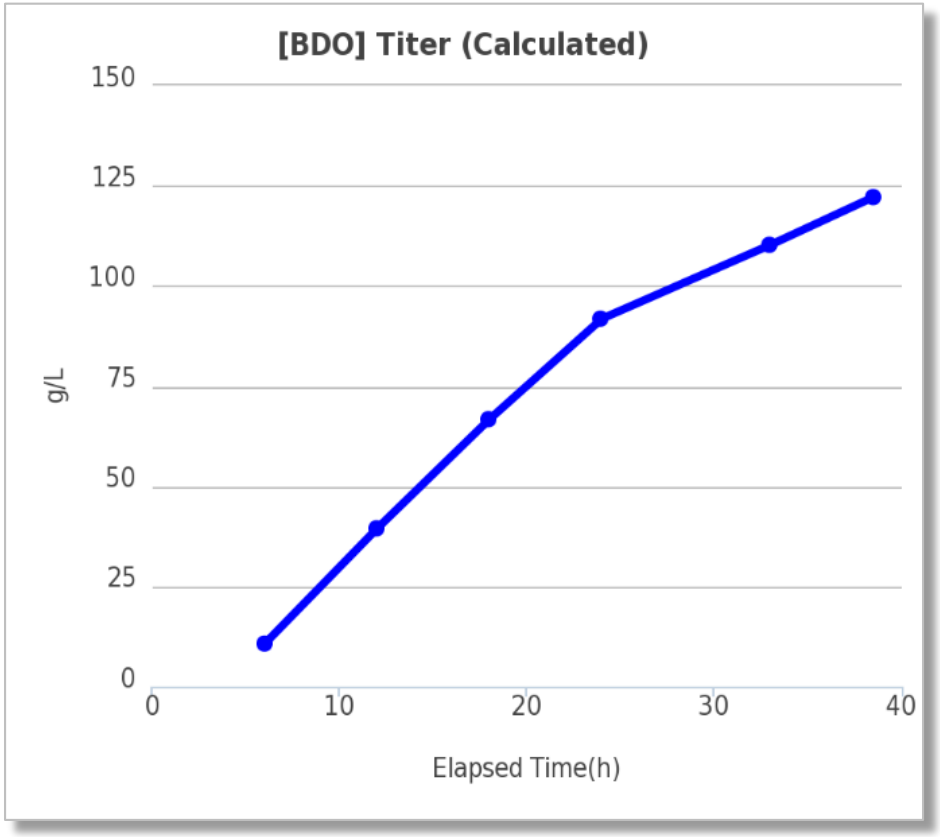
- Six design reports have been published.
- The reports evaluate the application of future research products in scaled-up processes showing potential for commercial relevance and identify process scenarios that lead to achievement of 2017/2022 cost targets .

Conversion Design Report Pathways
Biological Conversion of Sugars to Hydrocarbons
Catalytic Upgrading of Sugars to Hydrocarbons
Ex-Situ Catalytic Pyrolysis
In-Situ Catalytic Pyrolysis
Fast Pyrolysis and Upgrading
Syngas to Mixed Alcohols to Hydrocarbons

Key Accomplishments - Genomatica

Genomatica was selected in 2011 under the BC Process Integration (PI) FOA and was awarded $5 million in BETO funding to develop an engineered organism and optimized fermentation process to enable the conversion of cellulosic sugars to 1,4-butanediol (BDO).

1,4-BDO Production with API-AVAP® Biomass Hydrolysate (agricultural residue)



DOE/NREL final validation

- 30 L scale fermentation w/API AVAP® hydrolysate
- Biomass-to-BDO strain, Latest XUM strain
- Co-utilized glucose and xylose, both depleted:
  - Glucose >99%
  - Xylose 96%
- Process optimization sped up run, finishing in <40 hrs
- Titer (122 g/L), Rate (3.1 g/L/hr) well above proposed final targets (70, 2.5); yield, lower than target.

genomatica

Key Accomplishments - GTI

- Competitive Awardee GTI patented a catalytic process known as IH^{2}®
  - Integrated Hydropyrolysis and Hydroconversion
  - Converts non-food biomass products directly to fuel with a 60% reduction in GHGs
  - Replacement gasoline and diesel range fuels at less than $2.50/gallon

- Have had a exclusive licensing agreement with CRI Catalyst Company in place since June 2013

Office Partnerships

Collaborations With Other Offices and Agencies

Department of Agriculture

Selected DOE collaboration activities with USDA Include:

- USDA Rural Development-Cooperative Service
- USDA/DOE Biomass Feedstocks Coordination Meetings
- Woody Biomass Utilization Group
- Defense Production Act
- Biomass Research & Development Initiative (BRDI)

Other DOE Offices

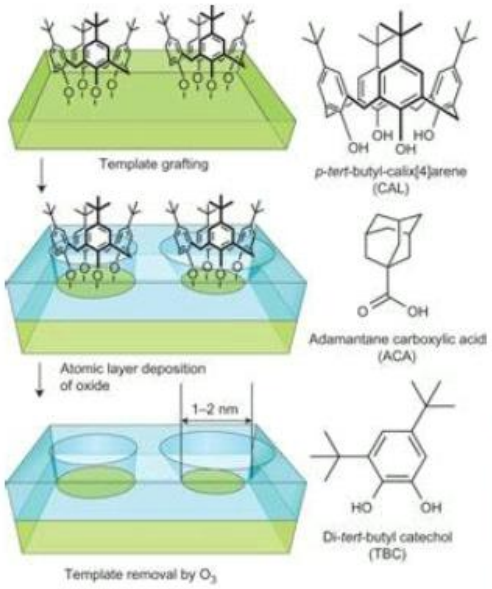
U.S. DEPARTMENT OF ENERGY
Office of Science

arpa·e
CHANGING WHAT'S POSSIBLE

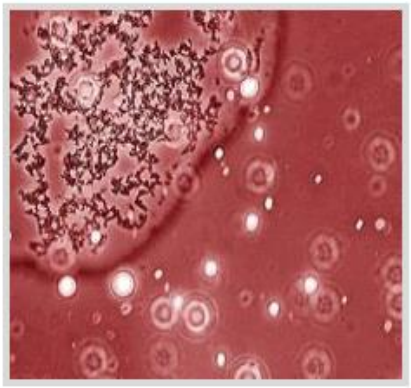
Collaboration with the Office of Science

Biological and Environmental Research Program - Basic Energy Sciences Program

- Overlapping R&D areas of interest
  - Energy crops
  - Systems biology
  - Climate change and sustainability
  - Photosynthesis
  - Catalysis



Nanosieves to improve catalyst specificity (Credit: Brandon O'Neil, Argonne EFRC)



Microbe secreting hydrocarbons (Credit: Eric Steen, JBEI)

- Biomass R&D Act
  - Biomass R&D Board and Working Groups
  - Biomass R&D Technical Advisory Committee
- Bridging Gaps Through Partnerships
  - Bioenergy Research Centers (JBEI, GLBRC, BESC)
  - Energy Frontiers Research Centers
  - Advanced Biofuels Process Demonstration Facility
- Complimentary FOAs
  - Released complimentary FOAs this year focusing on the basic and applied elements of sustainability with respect to crops and landscape design

U.S. DEPARTMENT OF ENERGY
Office of Science

ARPA-E Program

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arpa·e CHANGING WHAT'S POSSIBLE


BEEST


PETRO


Electrofuels


MOVE


RANGE


REMOTE

Transportation Energy Technologies

Stationary Energy Technologies

HEATS 

AMPED 

REACT 

SBIR/STTR 

METALS 

SWITCHES 

Solar ADEPT 

BEETIT 

GRIDS 

IMPACCT 

ADEPT 

GENI 

FOCUS 

ARPA-E Program cont.

PETRO: Plants Engineered to Replace Oil [Status: 12 projects active]

Targets the production of fuel molecules, such as oils and hydrocarbons, directly in the plant feedstock through metabolic engineering.

The program successfully generated a variety of crop feedstocks that accumulate at least 1% of the fuel molecule by DW, and has demonstrated a number of promising plants in small scale field trials. In parallel, multiple traits have been observed to increase photosynthetic efficiency. PETRO has also applied novel agronomic approaches to increase yields of the bioenergy crops under development.

REMOTE, Reducing Emissions using Methanotrophic Organisms for Transportation Energy [Status: 15 projects under active program management]

Targets the development of new methane bioconversion technologies for small scale, low CapEx gas-to-liquids (GTL) processing. Current GTL state-of-technology is challenged by high CapEx and technologically-complex processes. Bioconversion of methane is a viable option for GTL if technologies addressing energy efficient, carbon yield, and kinetics are developed with attention to cost.

The program objectives aim to develop new, more efficient biological routes to activate methane, engineer metabolic pathways to convert activated methane to liquid fuel with high energy density, and develop process intensification for methane bioconversion.

International Projects

- CA-02 Pyrolysis and Upgrading Collaboration with Canada
  - Combine U.S. and Canadian expertise to advance pyrolysis
  - Each country funds own activities
- U.S.-China collaboration - Thermochemical Conversion of Biomass
  - Combine and leverage expertise of both nations to advance thermochemical conversion of biomass to advanced biofuels
  - Supports MOU between U.S. and China
  - Supports thermochemical conversion to drop-in biofuels 2017 target
- Brazil Bilateral: Petrobras/Ensyn – NREL RD&D CRADA
  - Assessing traditional fast pyrolysis followed by upgrading to liquid fuels through refinery co-processing

Major Program Updates and Upcoming Activities for FY15

Recently Selected Projects

CHASE Alternates

- **SRI (Stanford) International** - bio-crude oil from algal biomass
- **RTI** - biomass carbon and energy recovery in a low pressure process

Carbon Fiber

- **Southern Research Institute** - conversion of sugars from non-food biomass to acrylonitrile
- **NREL** - pathways to bio-acrylonitrile

BCU

- **University of Wisconsin** - chemicals from biomass
- **API** - upgrade cellulosic sugars to solvents
- **NREL** - production of muconic acid from biogas
- **Natureworks** - fermentation process for the production of lactic acid
- **Vertimass** - ethanol into diesel fuel, gasoline, and jet fuel blend stocks

Bioenergy Technologies Office Incubator Selections

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

Seven projects selected in February 2015 to support technologies not represented in a significant way in the Office's current portfolio.

Metabolix, Inc.	• Development of non-genetically modified, non-food feedstock, Camelina sativa, to maximize oil yields per acre.
The Pacific Northwest National Laboratory	• Microalgae production directly from CO_2 in air at high productivities.
The Ohio State University	• Cellulosic butanol production process through novel metabolic engineering
The University of California Riverside	• Co-solvent pretreatment to high yields of clean fuel precursor fractions.
OPX Biotechnologies	• Production of cost-competitive C8 fatty acid derivatives from cellulosic sugars via novel metabolic engineering pathways.
Kiverdi, Inc.	• Process methods and genetic tools for the production of hydrocarbons in thermophilic bacteria that directly utilizes biomass-derived syngas .
Gas Technology Institute	• Catalytic conversion of biomass plus methane into very high yields of hydrocarbon liquid fuels and chemicals.

Multi-products Enabling Generalized Approaches to the BIOeconomy

- Fund R&D on process steps and integration for pathways to produce chemicals that enable biofuels
- Preference for functional-equivalents to petrochemicals (e.g. BPA, phthalates, etc.)
- Applications will specify complete pathways, ideally including fuels and products, identify one or more "barrier" R&D areas, and start/end metrics based on TEA.
- Topic areas:
  - TA1: Enabling/cross-cutting
  - TA2: Early-stage
  - TA3: Advanced ("deep pocket" entity/partner)

Workshop to be held in the Denver area the week of July 13th-17th. Exact details TBD.

Upcoming Conferences

- 37th Symposium on Biotechnology for Fuels and Chemicals
  - April 27th-30th at the Hyatt Regency La Jolla, San Diego CA

- TCBiomass2015
  - November 2nd-5th at the Westin Chicago River North, Chicago IL
  - Presentation abstracts due by April 10th

Those interested in potentially participating as session panelists for the Conversion session are encouraged to reach out to BETO staff ASAP.

- Conversion: New/emerging pathways and successes in existing pathways
- Innovations in Basic Science Across Agencies to Enable Bioenergy

BETO Conversion R&D Staff

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

Conversion Staff

- Kevin Craig (Program Manager)
- Bryna Guriel
- Liz Moore
- Prasad Gupte
- Nichole Fitzgerald (ORISE Fellow)
- Jay Fitzgerald (ORISE Fellow)
- Jeremy Leong (ORISE Fellow)

BETO Conversion R&D Staff

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

Conversion Contractors

- Josh Messner (CNJV, Manager)
- Beau Hoffman (CNJV)
- Rafael Nieves (CNJV)
- Jessica Phillips (CNJV)
- Clayton Rohman (CNJV)
- Diana Scott (CNJV)
- Trevor Smith (CNJV)
- Cynthia Tyler (CNJV)
- Art Wiselogel (CNJV)
- Andrea Bailey (BCS, Incorporated)
- Craig Brown (BCS, Incorporated)
- Ryan Livingston (BCS, Incorporated)

Thermo- and Biochemical Conversion Split

For the purpose of this review:

- **Biochemical conversion** technologies involve pathways that use sugars and lignin intermediates.
- **Thermochemical conversion** technologies involve pathways that use bio-oil and gaseous intermediates.

Moving forward we realize that the traditional division between biochemical and thermochemical conversion technologies will not sufficiently encompass the diversity of innovative technologies and focus has shifted to a simpler process flow in which the polymeric feedstock is deconstructed into intermediates which are then upgraded into products.

Conversion Reviewers

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

Biochemical	
Carol Babb*	Leidos
Kevin Gray	Intrexon
Daniel Lane	Saille Consulting LLC
Justin Stege	Independent Consultant
Bob Wooley	Biomass Ad Infinitum LLC

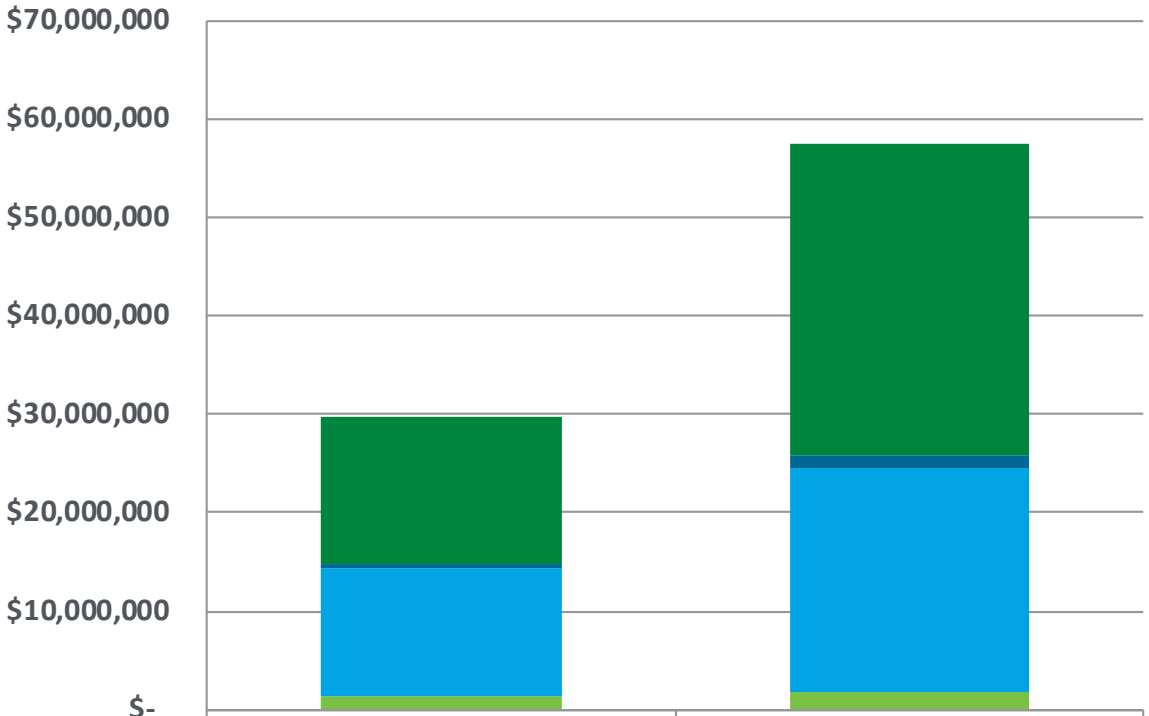
Thermochemical	
Don Stevens*	Cascade Science and Technology Research
Dan Burciaga	TRI
George Huff	BP
George Parks	Ret. ConocoPhillips
John Persichetti	Colorado School of Mines
Richard Quann	ExxonMobil

**** Lead Reviewer***

Thank you

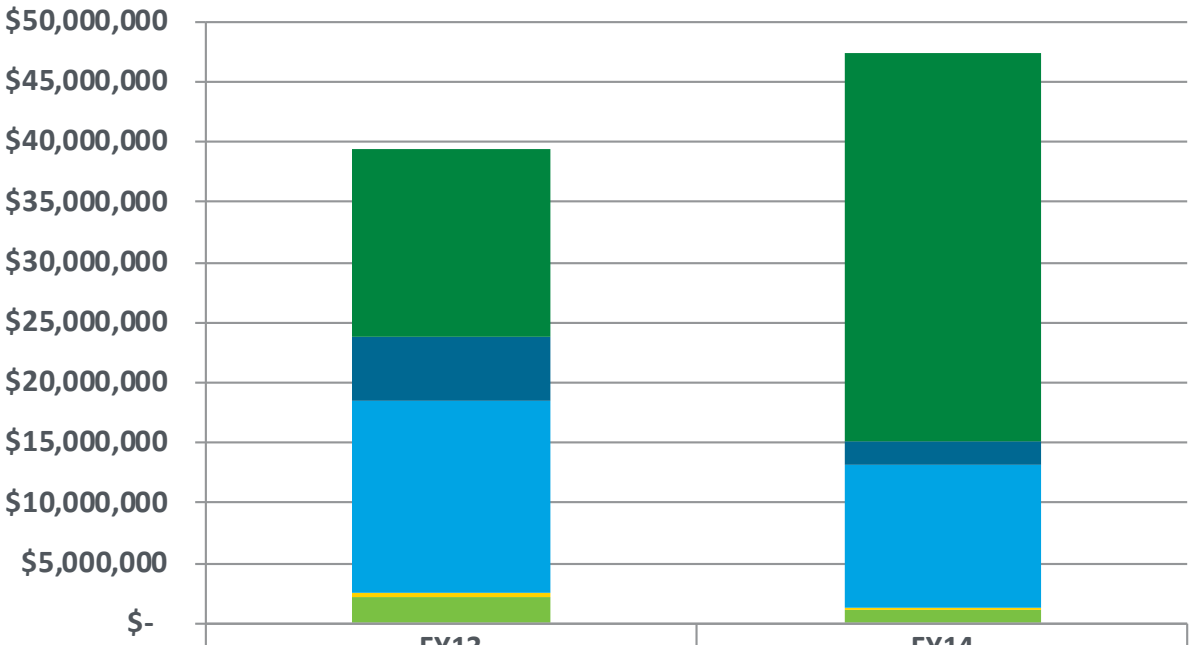
Extra Slides

Budget: Biochemical R&D (numbers after rescission)



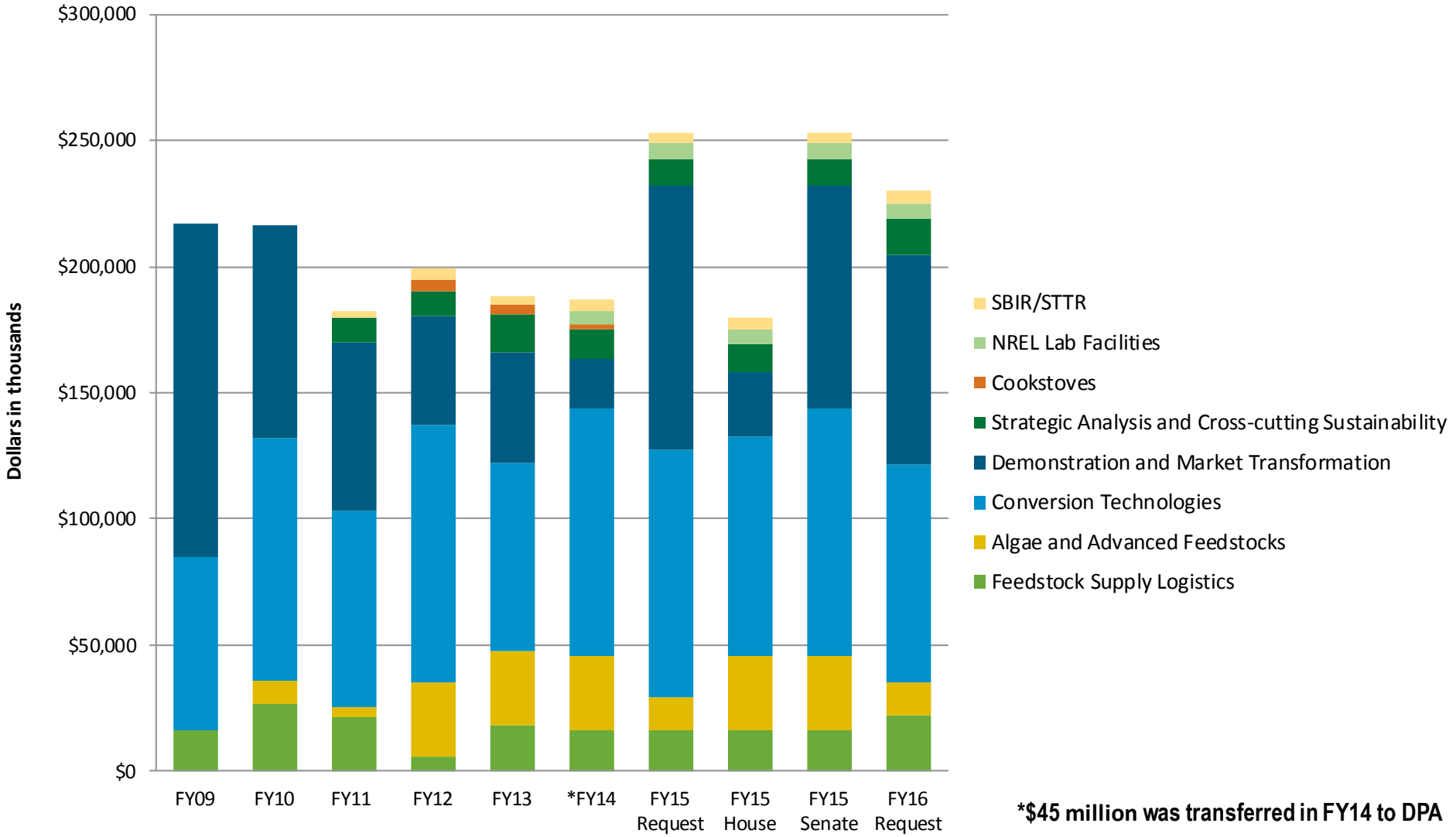
	FY13	FY14
Lab Core R&D	$14,910,627	$31,557,401
Analysis	$385,000	$1,358,000.00
Competitively Selected Projects	$13,052,705	$22,723,563
International	$-	$-
Administrative	$1,340,864	$1,822,715

Budget: Thermochemical R&D (numbers after rescission)



	FY13	FY14
Lab Core R&D	$15,563,279	$32,408,067
Analysis	$5,371,000	$1,922,500
Competitively Selected Projects and CRD	$16,079,109	$11,891,786
International	$281,700	$40,000
Administrative	$2,154,660	$1,181,366

BETO Funding History



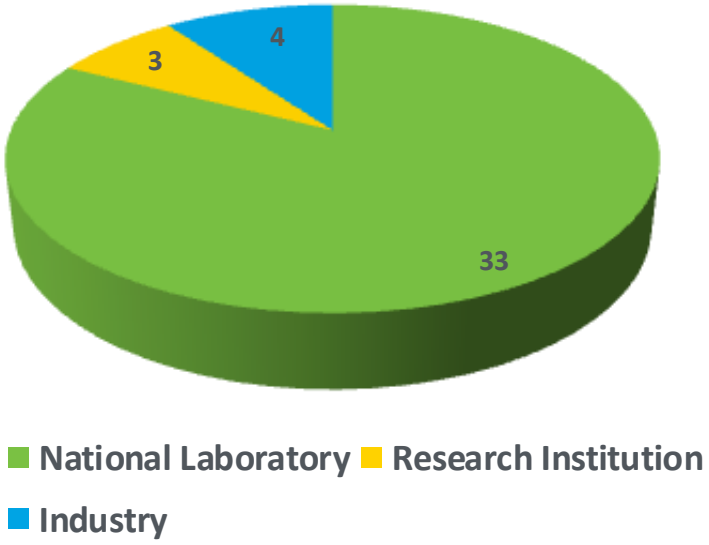
***$45 million was transferred in FY14 to DPA**

Biochemical Conversion Project Portfolio

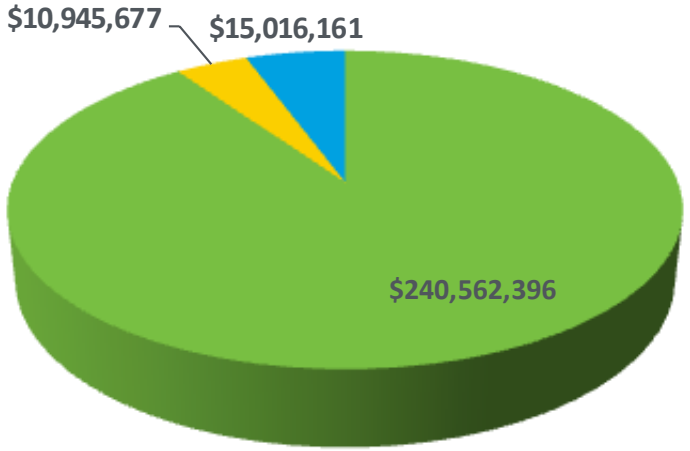
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

The Biochemical Technology Area will be reviewing 40 projects this week

Biochemical Performers to be Reviewed



Lifetime Project Budget

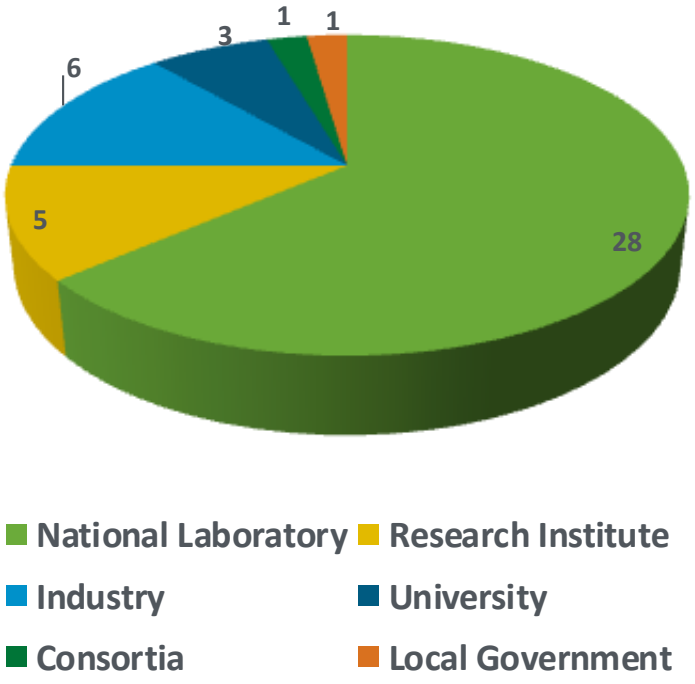


Thermochemical Conversion Project Portfolio

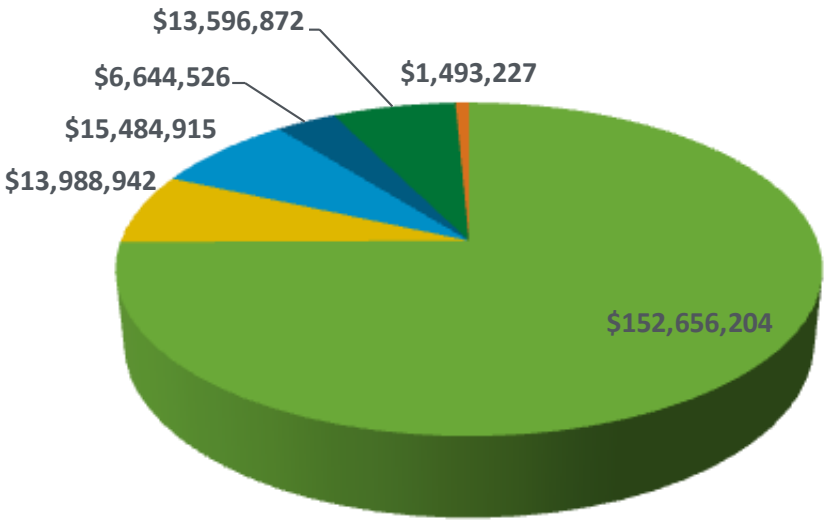
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

The Thermochemical Technology Area will be reviewing 44 projects this week

Thermochemical Performers to be Reviewed



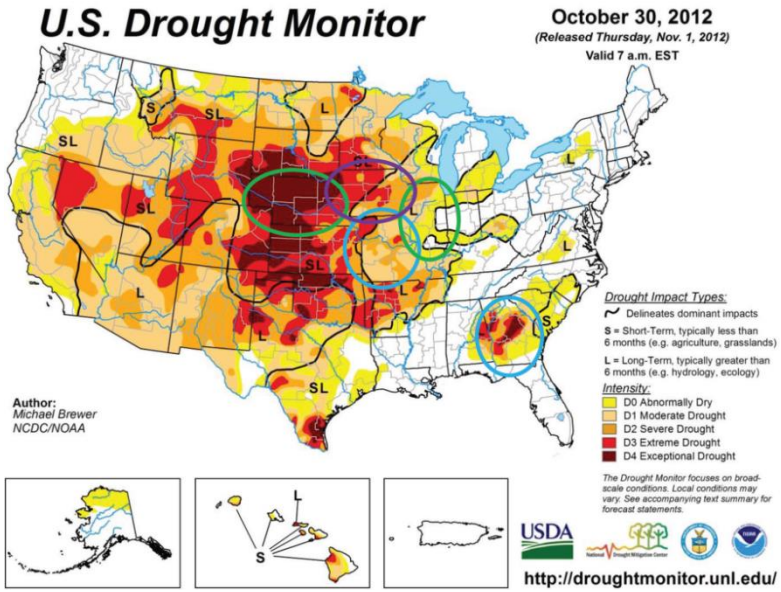
Lifetime Project Budgets

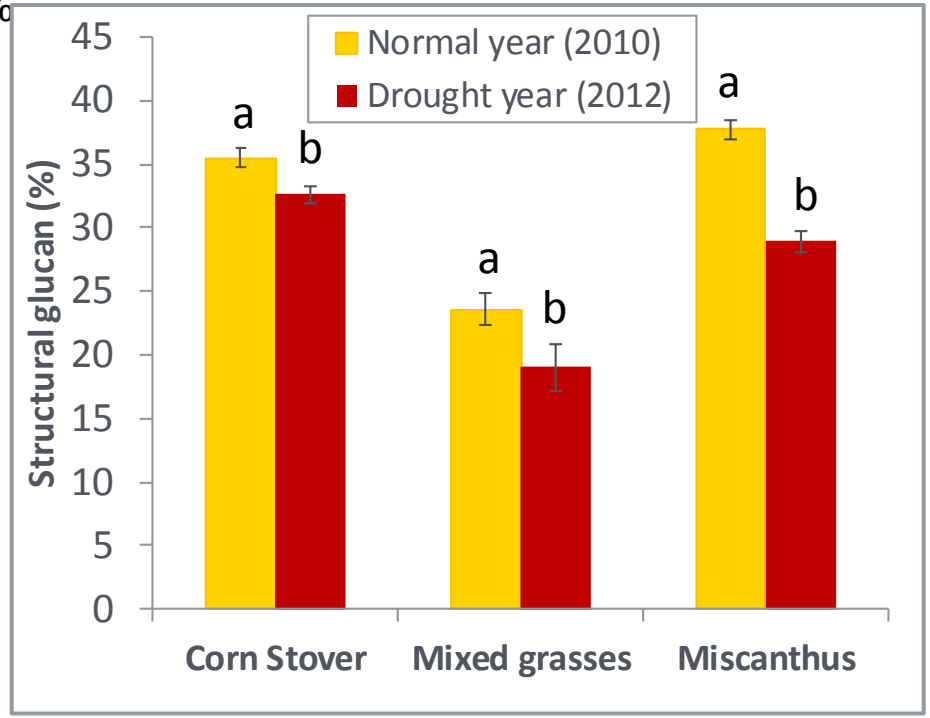


Regional Feedstock Partnership (RFP) Quality

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

- Over 2000 RFP samples (CRP grasses, *Miscanthus*, energycane, switchgrass, corn stover) characterized via NIR-prediction thru INL/NREL collaboration
- Subset investigated for impact of drought, where research indicated that:
  - Dry biomass yields were lower for mixed grasses and *Miscanthus*
  - Feedstock composition was significantly different i.e., structural glucan%
  - Theoretical ethanol yield decreased by 10 – 15%





"Drought effects on composition and yield for corn stover, mixed grasses, and Miscanthus as bioenergy feedstocks," Biofuels, 2014, 5(3), 275-291.

BRDI FOA released on February 25, 2015

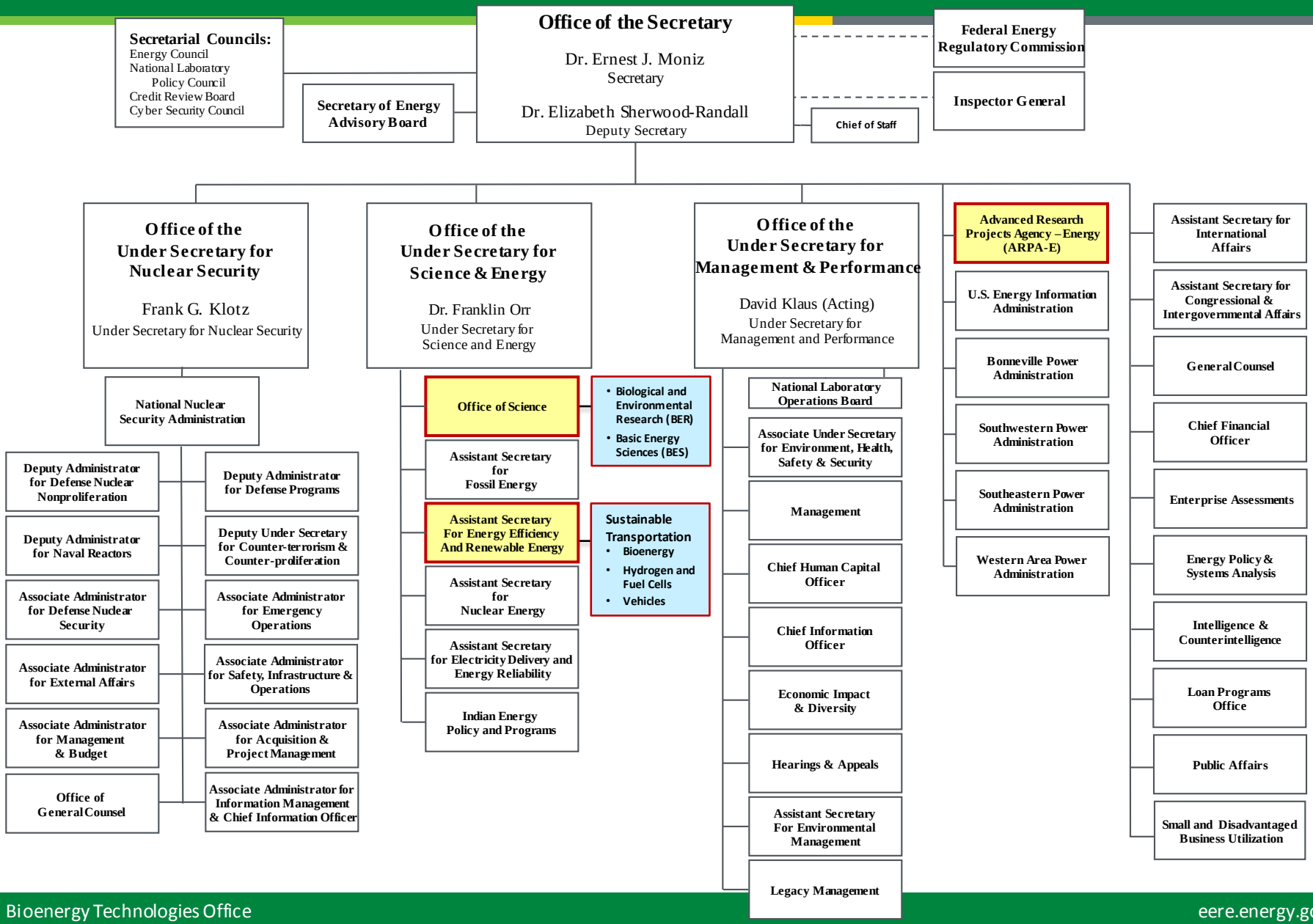
- USDA-NIFA-9008-004957 – Full solicitation information is available on Grants.gov
- This opportunity addresses USDA and DOE programmatic objectives, administrative roles, and areas of interest in implementing Biomass Research and Development Initiative grants.
  - USDA anticipates awarding grants and DOE anticipates awarding Cooperative Agreements under this FOA
- Concept Papers are being solicited to address one of the three technical topic areas:
  1. Feedstocks Development
  2. Biofuels and Biobased Products Development
  3. Biofuels and Biobased Products Development Analysis

Dates:

- BRDI RFA Release: 02/26/2015
- Concept Paper Due Date: 03/27/2015, 5:00 PM EST
- Full Application Due Date: 7/27/2015, 5:00 PM EST

Other DOE Program Offices

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



Office of Biological & Environmental Research (BER)

Current Funding Opportunity Announcements (FOAs):

- Systems Biology Research to Advance Sustainable Bioenergy Crop Development
  - DOE Genomic Science Program FOA DE-FOA-0001207
  - Systems biology research on biomass crops related to stress resilience/adaptation, resource use efficiency, and response to environmental variables
  - Genome-enabled research on interactions between plants, microbial communities, and soil ecosystems relevant to sustainable biomass production
- USDA/DOE Plant Feedstock Genomics For Bioenergy (Joint FOA)
  - DOE Genomic Science Program FOA DE-FOA-0001249
  - Genomics-based research on biomass plant traits related to plant response to pathogens, with a long-term focus on crop improvement

Reports & Strategic Planning Documents:

- DOE Genomic Science Program: 2014 Strategic Plan Update

  http://genomicscience.energy.gov/strategicplan/index.shtml
- Lignocellulosic Biomass for Advanced Biofuels & Bioproducts: 2014 Workshop Report

  http://genomicscience.energy.gov/biofuels/lignocellulose/index.shtml

Office of Basic Energy Sciences (BES)
Chemical Sciences, Geosciences and Biosciences Division

Basic Energy Sciences Annual Open Funding Opportunity Announcement

http://science.energy.gov/bes/funding-opportunities/

For information on all projects that are funded in BES:

Basic Energy Sciences Summary Report and FY 2014 Research Summaries

http://science.energy.gov/bes/research/

For information on the biosciences-focused programs in BES, Photosynthetic Systems and Physical Biosciences:

http://science.energy.gov/bes/csgb/research-areas/photosynthetic-systems/

http://science.energy.gov/bes/csgb/research-areas/physical-biosciences/

Open Recompetition of the Energy Frontier Research Center program resulted in 32 awards for FY 2014; 5 centers related to biosciences

http://science.energy.gov/bes/efrc/

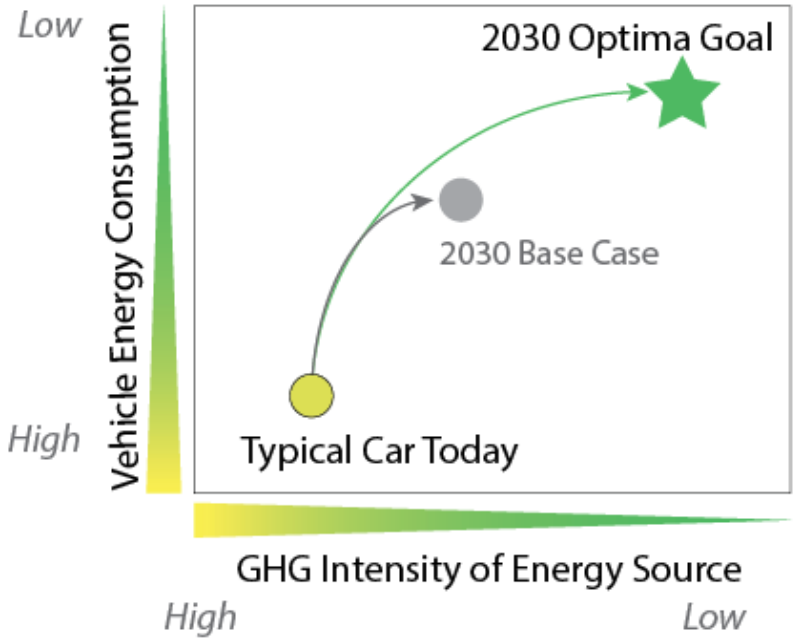
- Catalysis Center for Energy Innovation (CCEI); Dionisios Vlachos, University of Delaware
- Center for Direct Catalytic Conversion of Biomass to Biofuels (C3Bio); Maureen McCann, Purdue University
- Photosynthetic Antenna Research Center (PARC); Robert Blankenship, Washington University in St. Louis
- Center for Biological Electron Transfer and Catalysis (BETCy); John Peters, Montana State University
- Center for Lignocellulose Structure and Formation (CLSF); Daniel Cosgrove, Pennsylvania State University

Recent/ongoing competitive fuels awards with biofuel component – late FY 2014 competitive award

- Cummins Engine Co. : E85/Diesel Premixed Compression Ignition (EDPCI) Technology Demonstration of a Dual-Fuel Class 8 Truck
  - Advanced, low carbon engine combustion enabled using diesel and E85
  - Utilizes Reactivity Controlled Compression Ignition (RCCI) approach
  - Theoretical thermal efficiencies higher than conventional diesel

Optima (formerly NFVSO) Objectives

- Through co-optimization of fuels and engines, reduce per-vehicle petroleum consumption 30% vs. 2030 base case
  - Additional 7-14% reduction in engine fuel consumption
  - 20% reduction in fuel WTT emissions
  - Additional 9-14% fleet GHG reduction by 2040



- Develop new fuels and vehicles with higher performance that can be produced affordably, sustainably, and at scale
- Identify and mitigate barriers to wide-scale deployment of new fuels and vehicles
- Through a coordinated DOE and national lab effort, maximize value to widest range of stakeholders

PETRO program technical advancement

PETRO projects have observed very promising technical results, but need to identify new funding or deployment opportunities now.

Research Stage	Deployment Stage
Synthetic carbon fixation pathways	Cold tolerant sugarcane, and oil producing cane
Plant metabolic flux modeling	Terpene production in tobacco and high density production in the field
Photorespiratory channeling to increase specific metabolite yields in crop plants	Young pine trees over accumulating terpenes with efficient tapping methods
Increased photosynthetic activity through altered light harvesting antenna complex	Camelina with improved oil content for fuel use and terpene accumulation, and phenomic chambers capable of predicting field performance
Producing carboxysomes in plant cells to enhance photosynthesis	Traits to increase carbon flux to terpene and lipid production, stress tolerance, accelerate flowering, seed yield, and biomass production.

Key Accomplishments – Conversion/International Collaboration

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

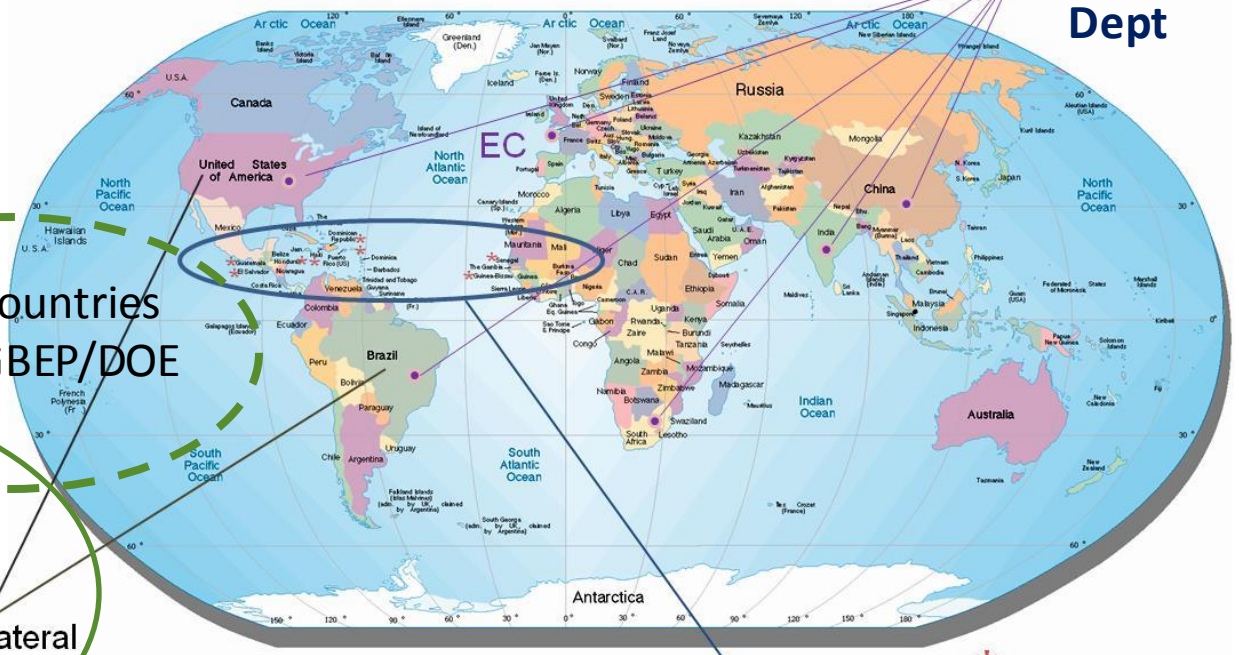
U.S. – Brazil MOU to Advance Cooperation on Biofuels

Aviation biofuels standards

NIST/INMETRO Global ethanol/biodiesel fuel standards

Global

US State Dept



Third countries MME/GBEP/DOE

March/2011

U.S.-Brazil Strategic Energy Dialogue

Biofuels RD&D

Bilateral

US DOE, EERE lead

USDA

March/2007

Third Countries *

US State Dept

Brazilian Government Ministries: Science, Technology and Innovation (MCTI); Mines and Energy (MME); Development, Industry and Foreign Trade (MDIC); Agriculture, Livestock and Supply (MAPA), led by the Ministry of External Relations

Response to Peer Review 2013 Recommendations

BC Recommendations:

- Recommend a more consistent and transparent collaboration with other offices—such as ARPA-E and the Office of Science
- There should be some leeway in the specificity of the hydrocarbon end product as Technology Area planning and development of FOAs progresses
- Program should consider ways to bring all of the laboratories' research up to a consistently high level
- Encourage the use of a graded level of metrics and milestones tailored to the TRL status of each project

TC Recommendations:

- Fund research at higher TRLs with larger-scale equipment
- Develop functional, consistent, process techno-economic models earlier in the process
- Increase the requirement for refining expertise or collaboration as part of all projects
- Focus more R&D and scale-up on processing equipment (i.e., feeders, reactors, filters, etc.) that will be used in real-world systems
- Require close out projects to document all equipment descriptions, analytical techniques and protocols, experimental procedures, and data obtained from both successful and less-than-successful experiments
- Future project presentations should clearly illustrate data transparency supported by material and energy balances
- Proactively encourage publishing innovations, including advanced analytical techniques, in leading peer-reviewed journals for information dissemination

Office of Basic Energy Sciences (BES)
Chemical Sciences, Geosciences and Biosciences Division

The BES Biosciences programs, Photosynthetic Systems and Physical Biosciences, support basic research on the physical, chemical and molecular mechanisms that plants and microbes use for energy capture, conversion and storage.

- Preapplications and Proposals are solicited through the Office of Science Annual FOA.
  - This FOA is the annual, broad, open solicitation that covers all of the research areas in the Office of Science and is open throughout the Fiscal Year (until Sept 30, 2015).
- The goal of BES Biosciences is to provide a basic understanding of the biological and biochemical processes that can provide foundational knowledge related to DOE's mission to efficiently capture and utilize solar energy and to convert renewable resources into fuels, chemicals and other energy-enriched products.
- Example Biosciences research areas:

- Light Harvesting in Natural Systems, Photon Capture and Transfer
- Charge Separation, Electron Transfer, Redox Reactions
- Carbon Fixation, RuBisCO and Calvin-Benson Cycle
- Processes and Mechanisms of Energy Capture and Conversion
- Carbon Storage in Organic Molecules
- Metabolism in Relation to Energy Storage and Use
- Application of Physical Science Tools to Address Structure/Function and Mechanistic Studies
- Active Site Protein Chemistry, Redox Reactions
- Regulation of Energy-Relevant Biological Reactions
- Biochemistry and Biophysics of Cell Architecture including Cell Wall
- Biosynthesis, Structure, and Self-Organizing Processes
- Assembly and Maintenance of Energy Transduction Systems