U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

2023 PROJECT PEER REVIEW

U.S. DEPARTMENT OF ENERGY
BIOENERGY TECHNOLOGIES OFFICE

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INTRODUCTORY LETTER

Dear colleagues,

In the spring of 2023, the U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE) Bioenergy Technologies Office (BETO) continued its long-standing commitment to transparency by executing the 11th biennial external review since 2005 of its research, development, and demonstration (RD&D) portfolio. Conducted in accordance with EERE Peer Review guidelines, the review provides an external assessment of the projects in BETO's portfolio and recommendations on BETO's overall technology focus and strategic direction. Results of the Project Peer Review will be considered in programmatic and funding opportunity decision-making.

This review is critical to the success of BETO's mission to develop and demonstrate technologies to accelerate reduction of greenhouse gas (GHG) emissions through the cost-effective, sustainable use of renewable carbon resources across the U.S. economy. At BETO, we are committed to accountability in project management and our role as stewards of taxpayer dollars aimed at achieving high-impact results. The Peer Review is an invaluable opportunity for independent reviewers to rigorously evaluate the approach, impact, and progress and/or outcomes of projects in the BETO portfolio, as well as the program strategies that guide technology area development. Further, it is a unique opportunity for external stakeholders to hear, in a compact and consistent format, about achievements from every corner of the portfolio.

The 2023 Peer Review comprised two levels of review: (1) individual projects were scored based on approach, impact, and progress and outcomes; and (2) each technology area portfolio was evaluated for overall strategy and progress. This report contains the results of both levels of review and the inputs of approximately 400 participants in the Peer Review process, including principal investigators, reviewers, and BETO's staff and contractors.

BETO thanks all the reviewers who participated in this review, as well as the 586 attendees of the Project Peer Review event. Our reviewers include some of the most experienced and knowledgeable experts in the bioenergy community, and we appreciate their insights and recommendations. Achieving the objectives of BETO depends on the effective management of all projects in BETO's existing portfolio and on the appropriate focus and structure of future initiatives. BETO values the input of all stakeholders in the bioenergy sector and looks forward to working with them in the years ahead to continue progress on the path toward building a successful bioenergy industry.

Sincerely,

Valerie Reed

Valerie Reed
Director, Bioenergy Technologies Office
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

EXECUTIVE SUMMARY

The Bioenergy Technologies Office (BETO) within the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy supports the research, development, and demonstration (RD&D) of technologies aimed at mobilizing domestic renewable carbon resources for the reduction of greenhouse gas emissions across the U.S. economy. BETO systematically prioritizes RD&D into technology opportunities across a range of emerging scientific breakthroughs and technology readiness levels in the subprogram areas illustrated in Figure 1. This approach supports a diverse portfolio while developing the most promising and widely applicable technologies, testing technologies as integrated processes, and demonstrating integrated processes to support scale-up. These technologies will use a broad variety of renewable carbon resources to produce increasing volumes of biofuels and bioproducts. More information on BETO's mission, goals, and strategic approaches can be found in the Bioenergy Technologies Office Multi-Year Program Plan.[1]

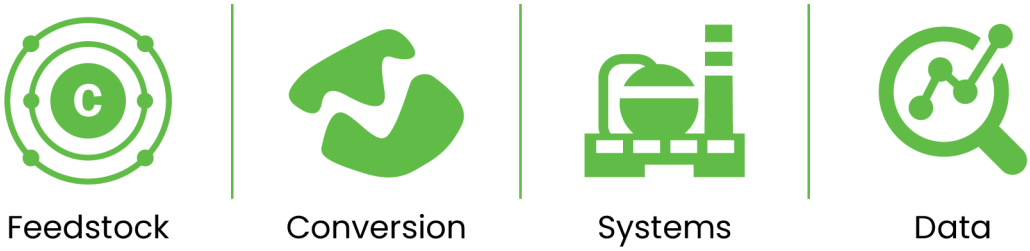

Figure 1. Bioenergy RD&D technologies

The biennial Peer Review process enables external stakeholders to provide feedback on the responsible use of taxpayer funding and develop recommendations for the most efficient and effective ways to accelerate the development of a bioenergy industry. This report includes the results of the Project Peer Review meeting held on April 3–7, 2023, in Denver, Colorado.

[1] BETO. 2023. *Bioenergy Technologies Office Multi-Year Program Plan*. Washington, D.C.: BETO. DOE/EE-2698. https://www.energy.gov/eere/bioenergy/articles/2023-multi-year-program-plan.

ACRONYMS AND ABBREVIATIONS

2,3-BDO	2,3-butanediol
3HB	3-hydroxybutyrate
3-HP	3-hydroxypropionic acid
6HDI	hexamethylene diisocyanate
7HDI	heptamethylene diisocyanate
AAD	arrested anaerobic digestion
AAS	Advanced Algal Systems
ABF	Agile BioFoundry
ABPDU	Advanced Biofuels and Bioproducts Process Development Unit
ABS	acrylonitrile butadiene styrene
ACSC	Advanced Catalyst Synthesis and Characterization
AD	anaerobic digestion
ADM	Archer Daniels Midland
AFT	American Farmland Trust
AI	artificial intelligence
AMMTO	Advanced Materials and Manufacturing Technologies Office
AMP	antimicrobial peptide
ANL	Argonne National Laboratory
AnMBR	anaerobic membrane bioreactor
ANOVA	analysis of variance
AOP	annual operating plan
APAD	advanced pretreatment and anaerobic digestion
ARC	Alder Renewable Crude
ARPA-E	Advanced Research Projects Agency – Energy
ARS	Agricultural Research Service
ASEC	Affordable and Sustainable Energy Crops
aTc	anhydrous tetracycline
ATD	alcohol to diesel
ATEC	Algae Technology Educational Consortium
ATJ	alcohol to jet
ATP	adenosine triphosphate
AUDACity	Arizona State University's direct air capture polymer-enhanced cyanobacterial bioproductivity
AVAP	American Value-Added Pulping
AWOEx	Advanced Wet Oxidation and Steam Explosion
AzCATI	Arizona Center for Algae Technology and Innovation
BAT	Biomass Assessment Tool
BDO	butanediol
BDT	bone dry ton
BEA	beta zeolite
BEEPS	BioEnergy Engineering for Products Synthesis
BEIOM	Bio-based circular carbon economy Environmentally-extended Input-Output Model
beta-KA	beta-ketoadipic acid

BETO	Bioenergy Technologies Office
BFL	Bioenergy Feedstock Library
BFNUF	Biomass Feedstock National User Facility
BHET	bis(2-hydroxyethyl terephthalate
BIC	Biofuels Information Center
BiCRS	biomass with carbon removal and storage
BILT	Biofuel Infrastructure, Logistics, and Transportation
BioC2G	Bio-Cradle-to-Grave
BIP	Biofuels Infrastructure Partnership
BKDL	ß-keto-d-lactone
BMP	best management practice
BNL	Brookhaven National Laboratory
BNSBA	Biofuels National Strategic Benefits Analysis
BOTTLE	Bio-Optimized Technologies to keep Thermoplastics out of Landfills and the Environment
BP	budget period
BPA	bisphenol A
BPM	bipolar membrane
BSM	Biomass Scenario Model
BTG	Biomass Technology Group
BTX	benzene, toluene, xylene
BUoB	best use of biomass
C1	one-carbon
C2+	two-carbon-plus
C4PE	Catalytic Carbon Conversion Center of Piloting and Excellence
CA	carbonic anhydrase
CapEx	capital expenditures
CAPSLOC	Combined Algal Processing for the Synthesis of Liquid Oleofuels and Products
CAS	conventional activated sludge
CBP	consolidated bioprocessing
CCC	countercurrent chromatography
CCE	carbon conversion efficiency
CCPC	Consortium for Computational Physics and Chemistry
CCS	carbon capture and storage
CCUS	carbon capture, utilization, and storage
CDM	Catalyst Deactivation Mitigation for Biomass Conversion
CEH	continuous enzymatic hydrolysis
CEJST	Climate and Economic Justice Screening Tool
CELF	co-solvent enhanced lignin fractionation
CF	carbon fiber
CFAnMBR	cloth filter anaerobic membrane bioreactor
CFB	circulating fluidized bed
CFC	carbon fiber composite
CFD	computational fluid dynamics
CFEP	carbon-fiber-reinforced epoxy composite

CFP	catalytic fast pyrolysis
CFRP	carbon-fiber-reinforced polymer
ChemCatBio	Chemical Catalysis for Bioenergy Consortium
CHJ	catalytic hydrothermolysis jet
CMA	critical material attribute
CNG	compressed natural gas
CO_2e	carbon dioxide equivalent
CO_2ER	CO_2 electrochemical reduction
CO_2RUe	CO_2 Reduction and Upgrading for e-Fuels Consortium
CoA	coenzyme A
COD	chemical oxygen demand
COF	covalent organic framework
Co-Optima	Co-Optimization of Fuels & Engines
CoPc	cobalt phthalocyanine
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CPD	Catalyst Property Database
CPP	critical process parameter
CQA	critical quality attribute
CRADA	cooperative research and development agreement
CRF	chemical-recovery-free
CRISPRa	CRISPR activation
CRISPRi	CRISPR interference
CSTR	continuous stirred-tank reactor
CSU	Colorado State University
CTT	cubical triaxial tester
CUBI	Catalytic Upgrading of Biochemical Intermediates
CUWP	Chemical Upcycling of Waste Plastics
CVWRF	Central Valley Water Reclamation Facility
DAC	direct air capture
DARPA	Defense Advanced Research Projects Agency
DBTL	design-build-test-learn
DEI	diversity, equity, and inclusion
DEIA	diversity, equity, inclusion, and accessibility
DEIP	diversity, equity, and inclusion plan
DEM	discrete element modeling
DFA	directed funding award
DFO	directed funding opportunity
DFT	density functional theory
DIC	dissolved inorganic carbon
DISCOVR	Development of Integrated Screening, Cultivar Optimization, and Verification Research
D-LEWT	distributed low-energy wastewater treatment
DMA	data, modeling, and analysis
DMCO	dimethyl cyclooctanes
DMR	deacetylation and mechanical refining
DOE	U.S. Department of Energy

DRIFTS	diffuse reflectance infrared Fourier transform spectroscopy
EAST	Emerging and Supporting Technologies
ECS	Empire Comfort System
ECO_2R	electrochemical reduction of CO_2
EEDIP	Energy and Environment Diversity Internship Program
EEEJ	energy equity and environmental justice
EERE	Office of Energy Efficiency and Renewable Energy
EJ	environmental justice
EJScreen	Environmental Justice Screening and Mapping Tool
EMPLOY	Environmentally extended Multi-regional Projection of Lifecycle and Occupational energY futures
EOL	end of life
EPA	U.S. Environmental Protection Agency
EPSCoR	Established Program to Stimulate Competitive Research
EROI	energy return on investment
ETAP	Escaped Trash Assessment Protocol
EtOH	ethanol
EXAFS	extended X-ray absorption fine structure
FAIR	findable, accessible, interoperable, and reusable
FCC	fluid catalytic cracking
FCIC	Feedstock-Conversion Interface Consortium
FDA	U.S. Food and Drug Administration
FD-CIC	Feedstock Carbon Intensity Calculator
Fe-B	iron-boride
FEM	finite element method
Fire MAPS	Fire Monitoring, Alerts, and Performance System
FMEA	failure mode and effect analysis
FOA	funding opportunity announcement
FOG	fats, oils, and greases
FPEAM	Feedstock Production Emissions to Air Model
FPO	fast pyrolysis oil
FTC	freeze tape casting
FTOT	Freight and Fuel Transportation Optimization Tool
FTS	Fischer-Tropsch synthesis
FY	fiscal year
GAI	Global Algae Innovations
GAMS	General Algebraic Modeling System
GCAM	Global Change Analysis Model
GDE	gas diffusion electrode
GGE	gasoline gallon equivalent
GHG	greenhouse gas
GMO	genetically modified organism
GREENSCOPE	Gauging Reaction Effectiveness for the ENvironmental Sustainability of Chemistries with a Multi-Objective Process Evaluator
GREET	Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies
GT	Global Thermostat

GTAP	Global Trade Analysis Project
GTI	Gas Technology Institute
GTL	gas to liquid
GWP	global warming potential
HBCU	historically Black college or university
HCU	hydrothermal cleanup
HDCJ	hydrotreated depolymerized cellulosic jet
HDO	hydrodeoxygenation
HEFA	hydroprocessed esters and fatty acids
HObT	Host Onboarding Tool
HOD	Host Onboarding & Development
HOG	high-octane gasoline
HPC	high-performance computing
HSI	hyperspectral imaging
HTL	hydrothermal liquefaction
IAA	indole-3-acetic acid
IAB	industry advisory board
IACMI	Institute for Advanced Composites Manufacturing Innovation
IBR	integrated biorefinery
IBRF	Integrated Biorefinery Research Facility
ICAO	International Civil Aviation Organization
IEO	Industry Engagement and Outreach
IFD	issued for design
IH^2	Integrated Hydropyrolysis and Hydroconversion
ILUC	induced land use change
INL	Idaho National Laboratory
InMAP	Intervention Model for Air Pollution
IP	intellectual property
IPA	isopropyl alcohol
IRR	internal rate of return
ISPR	in situ product recovery
JUST-R	Justice Underpinning Science and Technology Research
KDF	Knowledge Discovery Framework
LANL	Los Alamos National Laboratory
LBNL	Lawrence Berkeley National Laboratory
LCA	life cycle analysis
LCFS	low-carbon fuel standard
LCOE	levelized cost of energy
LIBS	laser-induced breakdown spectroscopy
LOUP	Lubricating Oils From Upcycled Plastics
LUC	land use change
MARINER	Macroalgae Research Inspiring Novel Energy Resources
MBL	alpha-methylene butyrolactone
MBSP	minimum biomass selling price
MEA	membrane electrode assembly
MEG	monoethylene glycol

MEK	methyl ethyl ketone
MES	microbial electrosynthesis
MESP	minimum ethanol selling price
MFSP	minimum fuel selling price
ML	machine learning
MLP	multilayer plastic
MMA	methyl methacrylate
MMT	million metric tons
MOOC	massive open online course
MOT	mild oxidative treatment
MPa	megapascals
MRF	materials recovery facility
MSI	minority-serving institution
MSP	minimum selling price
MSSP	minimum sugar selling price
MSU	Montana State University
MSW	municipal solid waste
MTO	methanol to olefins
MVL	methylene valerolactone
MYPP	Multi-Year Program Plan
NADH	nicotinamide adenine dinucleotide
NGO	nongovernmental organization
NIR	near-infrared
NMR	nuclear magnetic resonance
NMSW	nonrecyclable municipal solid waste
NPV	net present value
NRCS	Natural Resources Conservation Service
NREL	National Renewable Energy Laboratory
NSF	National Science Foundation
NTP	nonthermal plasma
NZTT	Net-Zero Carbon Fuels Technical Team
OEM	original equipment manufacturer
OFS	oleo-furan surfactant
OpEx	operating expenditures
ORNL	Oak Ridge National Laboratory
OSN	organic solvent nanofiltration
OSRO	organic solvent reverse osmosis
OSU	Oregon State University
P3-HP	poly(3-hydroxy)propionate
PA66	polyamide 66
PAA	polyacrylic acid
PABP	performance-advantaged bioproduct
PAM	polyacrylamide
P&O	progress and outcomes
PBAT	polybutylene adipate terephthalate
PBR	photobioreactor

PC	phycocyanin
PCA	principal component analysis
PCR	post-consumer recycled
PDO	pentanediol
PDU	process development unit
PE	polyethylene
PEM	polymer electrolyte membrane
PET	polyethylene terephthalate
PFAS	per- and polyfluoroalkyl substances
PFOS	perfluorooctane sulfonic acid
PGM	platinum group metal
PHA	polyhydroxyalkanoate
PHB	polyhydroxybutyrate
PHU	polyhydroxyurethane
PHW	post-hydrothermal liquefaction wastewater
PI	principal investigator
PISU	Process Integration and Scale-Up
PKS	polyketide synthase
PLA	polylactic acid
PM	particulate matter
pMBL	poly(alpha-methylene butyrolactone)
pMMA	polymethyl methacrylic acid
PNNL	Pacific Northwest National Laboratory
PO	polyolefin plastic
PolyID	Polymer Inverse Design
POLYSYS	Policy Analysis System Model
PP	polypropylene
PTS	phase-transition sorbent
PTU	polythiourethane
PU	polyurethane
PUP	polyurethane precursor
PVC	polyvinyl chloride
PVDF	polyvinylidene difluoride
QbD	quality by design
QEG	Quasar Energy Group
qPCR	quantitative polymerase chain reaction
R&D	research and development
RAB	Revolving Algal Biofilm
RABR	Rotating Algae Biofilm Reactor
RBEM	Regional BioEconomy Model
RCF	reductive catalytic fractionation
RCFP	reactive catalytic fast pyrolysis
RCR	Renewable Carbon Resources subprogram
RD&D	research, development, and demonstration
ReEDS	Regional Energy Deployment System
REMADE	Reducing Embodied Energy and Decreasing Emissions

ResIn	Responsible Innovation for Highly Recyclable Plastics
RFS	Renewable Fuel Standard
RIN	renewable identification number
RMP	risk management plan
RMPG	Risk Management Plan Guidance
RNG	renewable natural gas
RPO	residual pyrolysis oil
RTI	Research Triangle Institute
SAF	sustainable aviation fuel
SAFFiRE	Sustainable Aviation Fuel From [i] Renewable Ethanol
SAMPE	Society for the Advancement of Material and Process Engineering
SBI	Stove Builder International
scfm	standard cubic feet per minute
sCO_2	supercritical carbon dioxide
SCP	single-cell protein
SDI	Systems Development and Integration
SDSMT	South Dakota School of Mines and Technology
SE-CLG	sorption-enhanced chemical looping gasification
SepCon	Bioprocessing Separations Consortium
SMART	specific, measurable, achievable, relevant, and time-bound
SME	subject matter expert
SMR	steam methane reforming
SNL	Sandia National Laboratories
SNP	single nucleotide polymorphism
SOA	state of the art
SOC	soil organic carbon
SoCalGas	Southern California Gas Company
SOEC	solid oxide electrolysis cell
SOPO	statement of project objectives
SOT	state of technology
SPD	synthetic paraffinic diesel
SPERLU	Selective Process for Efficient Removal of Lignin and Upgrading
STH	syngas to hydrocarbons
STRAP	solvent-targeted recovery and precipitation
SUP	Scale-Up Portfolio
SUPERBEEST	Scaling Up PERennial Bioenergy Economics and Ecosystem Services Tool
SUPF	single-use flexible plastic film
SWAT-C	Soil and Water Assessment Tool – Carbon
SWIFT	Single-Pass, Weather Independent Fractionation Technology
TA	technical assistance
TAL	triacetic acid lactone
TCPDU	Thermal and Catalytic Process Development Unit
TD-NMR	time-domain nuclear magnetic resonance
TDO	thermal deoxygenation
TEA	techno-economic analysis

TEG	thermoelectric generator
TEM	techno-economic model
Tg	glass transition temperature
THP	thermal hydrolysis processing
Tm	melting temperature
TOS	time on stream
TPA	terephthalic acid
TPD	ton per day
TPU	thermoplastic polyurethane
TRL	technology readiness level
TRY	titer, rate, and yield
TuFF	Tailorable Universal Feedstock for Forming
Tv	vitrimer transition temperature
UD-CCM	University of Delaware Center for Composite Materials
UHS	unhydrolyzed solids
UIUC	University of Illinois Urbana-Champaign
UMaine	University of Maine
UNM	University of New Mexico
USDA	U.S. Department of Agriculture
U.S. DRIVE	Driving Research and Innovation for Vehicle Efficiency and Energy Sustainability
USFS	U.S. Forest Service
VFA	volatile fatty acid
VGO	vacuum gas oil
VOC	volatile organic compound
VolCat	volatile catalyst
W2X	waste to X
WATER	Water Analysis Tool for Energy Resources
WBS	Work Breakdown Structure
W-C	tungsten-carbide
WRRF	water resource recovery facility
WSU	Washington State University
WTE	waste-to-energy
WWTF	wastewater treatment facility
XANES	X-ray absorption near edge structure
XPS	X-ray photoelectron spectroscopy
XRF	X-ray fluorescent
ZSM-5	Zeolite Socony Mobil–5

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INTRODUCTION

The Project Peer Review meeting took place April 3–7, 2023, in Denver, Colorado. The Peer Review brought together reviewers, project performers, Bioenergy Technologies Office (BETO) staff, and stakeholders along the entire bioenergy supply chain. Projects were systematically reviewed by 69 external subject matter experts from industry, academia, nonprofits, and government. BETO's funding portfolio was presented in 12 technology areas:

- Advanced Algal Systems
- Agile BioFoundry
- Biochemical Conversion and Lignin Utilization
- Carbon Dioxide Utilization
- Catalytic Upgrading
- Data, Modeling, and Analysis
- Feedstock-Conversion Interface Consortium
- Feedstock Technologies
- Performance-Advantaged Bioproducts, Bioprocessing Separations, and Plastics
- Organic Waste Conversion
- Systems Development and Integration: Emerging and Supporting Technologies
- Systems Development and Integration: Scale-Up.

Each review session included a technology area overview presentation that linked the projects in the portfolio to the technology area challenges and the program strategy for measuring progress and managing deliverables toward outcomes. A panel of independent reviewers reviewed and scored individual projects within each session and provided recommendations regarding the strategy and progress of the technology area. Results of the 2023 BETO Peer Review may be used to help inform programmatic decision-making, modify or discontinue existing projects, guide future funding opportunities, and support other budget and strategic planning objectives.

The 303 project presentations reviewed represent a total U.S. Department of Energy (DOE) investment of more than $561 million and cover activities that incurred costs from fiscal years (FY) 2021–2023. Figures 2 and 3, respectively, depict the number of presentations reviewed by technology area session and the associated funding allocation.

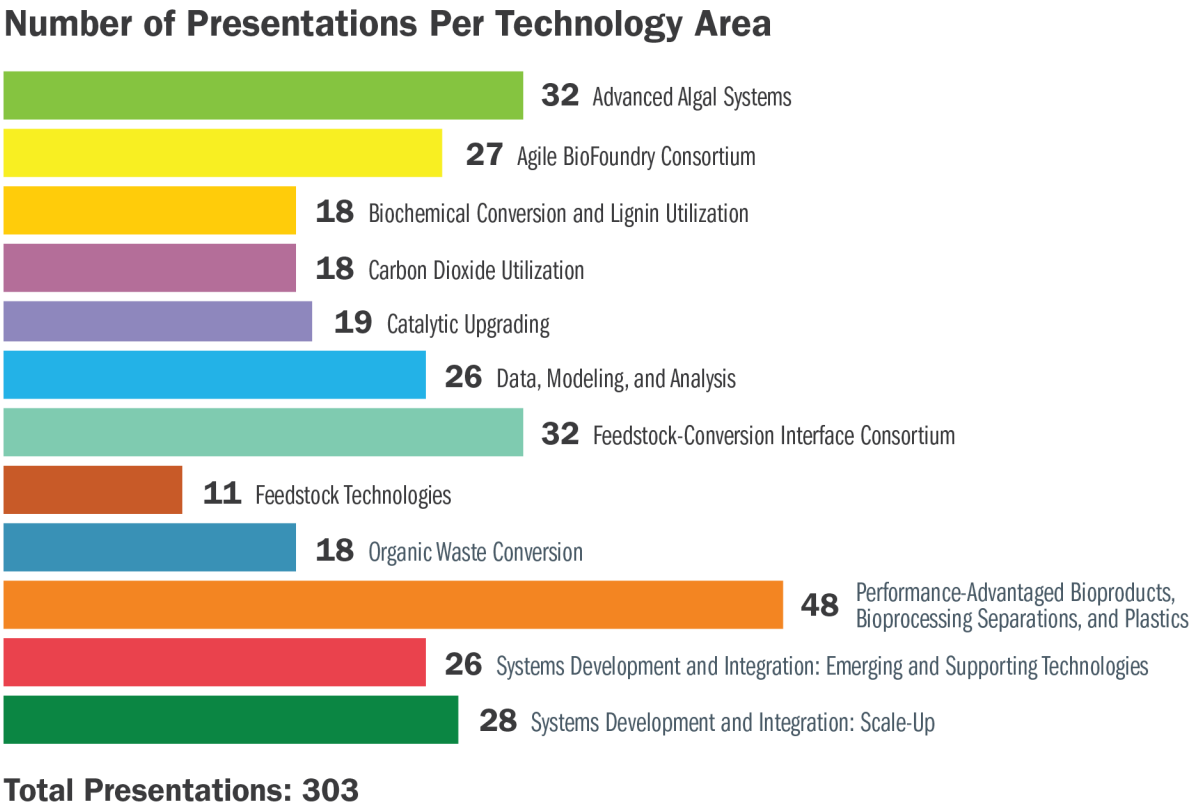

Figure 2. Number of presentations by technology area session

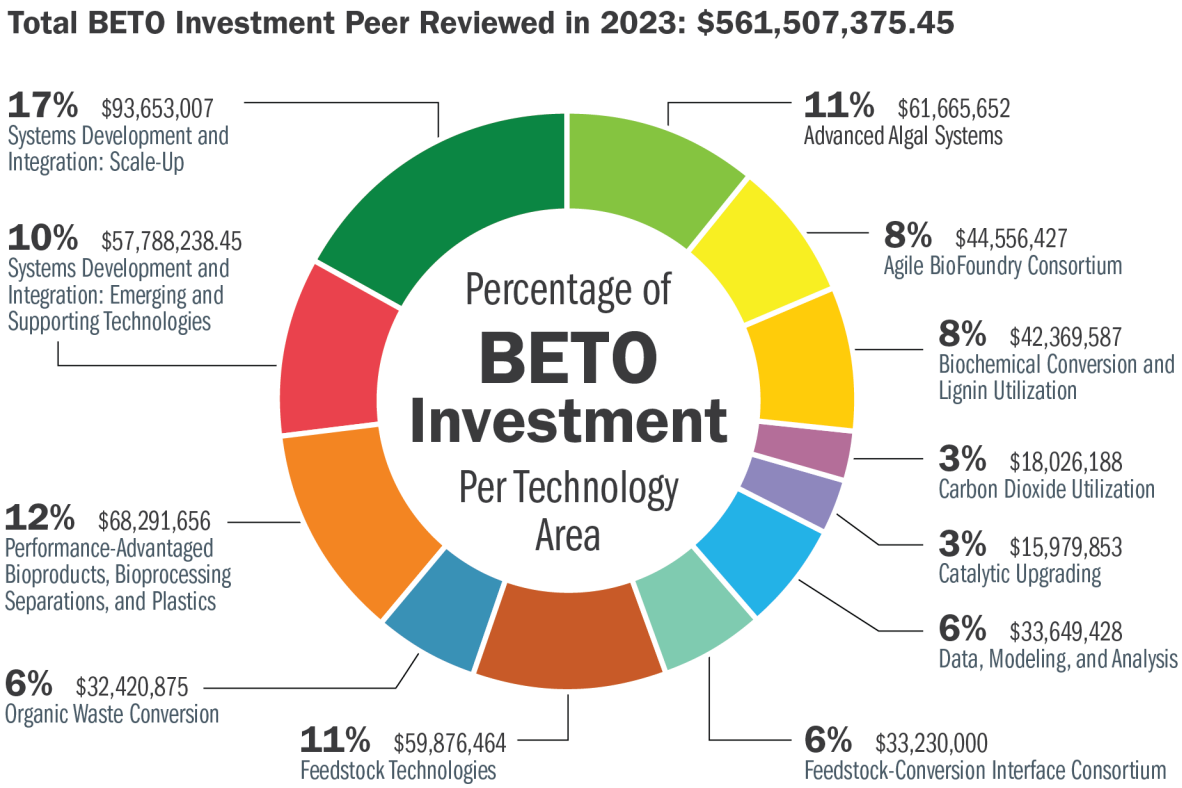

Figure 3. Total BETO funding of reviewed activities by technology area session

ROLES AND RESPONSIBILITIES

The BETO 2023 Peer Review was planned by an internal planning committee composed of BETO federal and contractor staff designated with the responsibility for developing and coordinating all aspects of the review process in compliance with EERE standards for conducting Project Peer Reviews. This committee included a federal lead and contractor support for each of the technology areas, as well as a federal Peer Review chair responsible for all aspects of the overall process, with a coordination and execution support team.

The reviews were conducted by individuals external to BETO with expertise in their fields and organized into review panels for each of the technology area sessions. The Advanced Algal Systems and Performance-Advantaged Bioproducts, Bioprocessing Separations, and Plastics technology areas hosted two sessions with separate panels due to their high number of projects. The review panels for each technology area consisted of four to seven external individuals selected based on technical expertise and professional qualifications in their designated technology area. Efforts were made to ensure experiential, institutional, and geographic diversity within each review panel by including a mix of reviewers from industry, academia, and federal agencies, with a range of expertise in relevant focus areas. Additionally, BETO proactively sought out expertise from outside of established networks with external calls for reviewers, and then made selections through a lens of improving diversity, equity, and inclusion in the makeup of the panels. Reviewers were required to sign legal agreements confirming an absence of a conflict of interest with the projects they reviewed. Final decisions on reviewer selection were made by the internal planning committee, with final approval by BETO's director. In addition, one reviewer on each panel was designated as the lead reviewer. In most cases, lead reviewers had previous experience participating as a reviewer in a prior BETO Peer Review. The extra responsibilities of the lead

reviewer included gathering the individual reviewer comments and scores and synthesizing them into a summary report for inclusion in this document.

Table 1 lists the members and affiliations of the lead reviewers of each panel. Members of each technology area review panel are listed within each technology area session summary.

Table 1. Lead Reviewers

Review Session	Name	Affiliation
Advanced Algal Systems	Lora Cameron-Landis	Lonza
Advanced Algal Systems	Tyler Johannes	University of Tulsa
Agile BioFoundry	Karen Draths	Michigan State University
Biochemical Conversion and Lignin Utilization	Lisette Tenlep Akers	LignoBio
Carbon Dioxide Utilization	Charles McCrory	University of Michigan
Catalytic Upgrading	Cory Phillips	Air Company
Data, Modeling & Analysis	Jason Jones	ICF
Feedstock Technologies	Jingxin Wang	West Virginia University
Feedstock-Conversion Interface Consortium	Phil Weathers	Weathers Associates Consulting
Organic Waste Conversion	Samantha MacBride	New York Department of Environmental Protection
Performance-Advantaged Bioproducts, Bioprocessing Separations, and Plastics	Sharon Haynie	Hypatia Technology Works
Performance-Advantaged Bioproducts, Bioprocessing Separations, and Plastics	Michael Mang	Danimer Scientific
Systems Development and Integration: Emerging and Supporting Technologies	Gene Petersen	Independent consultant
Systems Development and Integration: Scale-Up	Ray Miller	Verdecute Consulting

PROJECT EVALUATION CRITERIA

Reviewers evaluated each project on the following criteria: approach, progress and outcomes, and impact. Reviewers provided a numeric score per criterion, as well as written comments to support their scoring.

- **Approach**—Projects were evaluated on the degree to which:
    - The project performers have developed an approach with substantial merit to advance the state of the art, as relevant to the defined BETO program and technology area goals.
    - The project performers have developed an approach with significant potential for innovation in its application.
    - The project performers have a clear management plan and successful implementation strategy that includes risk identification and mitigation strategies.
    - The project provides routes for communication and collaboration with related projects and/or advisory boards, if appropriate.
    - If applicable, the project has an adequate approach to addressing diversity, equity, and inclusion in their project plan.

- **Progress and outcomes**—Projects were evaluated on the degree to which:
    - The project has made appropriate progress toward addressing the project goal(s).
    - The accomplishments have been achieved on schedule with the planned approach and, if relevant, the risk mitigation strategies have been employed to maintain project progress.
- **Impact**—Projects were evaluated on the degree to which:
    - The project demonstrated a clear connection of project approach to the potential for significant impact and outcomes.
    - The project has clear commercialization potential or has used or plans to use industry engagement to guide project deliverables, as relevant.

Scores ranged from 5 (outstanding) to 1 (unsatisfactory) per the rubric in Table 2.

Table 2. 2023 BETO Project Peer Review Scoring Rubric

Outstanding	Good	Satisfactory	Marginal	Unsatisfactory
5	4	3	2	1
All aspects of the criterion are comprehensively addressed. There are significant strengths and no more than a few—easily correctible—weaknesses.	All aspects of the criterion are adequately addressed. There are significant strengths and some weaknesses. The significance of the strengths outweighs most aspects of the weaknesses.	Most aspects of the criterion are adequately addressed. There are strengths and weaknesses. The significance of the strengths slightly outweighs aspects of the weaknesses.	Some aspects of the criterion are not adequately addressed. There are strengths and significant weaknesses. The significance of the weaknesses outweighs most aspects of the strengths.	Most aspects of the criterion are not adequately addressed. There may be strengths, but there are significant weaknesses. The significance of the weaknesses outweighs the strengths.

FORMAT OF THE REPORT

Information in this report has been compiled as follows and is based on the following sources:

1. **Peer review report introduction:** This section contains overview information on the Peer Review process, roles and responsibilities, and project evaluation criteria.

2. **Technology area summaries:** This section contains 12 chapters that represent the comprehensive evaluation for each technology area reviewed. Each chapter includes:

    A. **Introduction:** An overview of the technology area's project portfolio, including total funding of the projects reviewed and percentage of total BETO project portfolio.

    B. **Review panel members:** A list of names and affiliations of the independent subject matter experts who provided project evaluations and contributed to the review panel summary report.

    C. **Review panel summary report:** This summary of project evaluations provides insight regarding the technology area's overall strategy and progress. This section was drafted by the lead reviewer for each technology area in consultation with the full review panel. Consensus among the reviewers was not sought, and reviewers were asked to include any differences of opinion along with their recommendations.

    D. **Technology area programmatic response:** Represents the program's official response to the recommendations provided in the review panel summary report.

    E. **Project evaluations:** Includes the results of each project evaluation, including the following elements:

        i. **Project name and the lead project performer organization:** The full project name is listed as the heading, followed by the lead project performer's organization.

        ii. **Average project score per review criterion:** A bar chart depicts the average scores for each evaluation criterion, the range of scores per criterion given to the project by the individuals within the review panel, the average project score, and the average of all the projects in the technology area per criterion.

        iii. **Summary table:** Reference information about the project, which includes the recipient organization, principal investigator (PI), project dates, and total DOE funding.

        iv. **Project descriptions:** Project abstracts were submitted by each project performer.

        v. **Reviewer comments:** Verbatim comments made by the review panel, edited only for grammar and clarity. Each comment response represents the opinion of one reviewer. Reviewers were not asked to develop consensus remarks, and in most cases the reviewers did not discuss their overall comments on each project with one another. In a limited number of cases, reviewer remarks deemed inappropriate or irrelevant were excluded from the final report.

        vi. **PI response to reviewer comments:** The response to the reviewer comments provided by the project performers. Responding to reviewer comments was optional.