

Systems Development and Integration – Emerging and Supporting Technologies

April 3, 2023

Robert Natelson

Technology Manager

Introductions – BETO Systems Development and Integration



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Remy Biron
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Bryce Finch
Project Monitor



Kelly Nguyen
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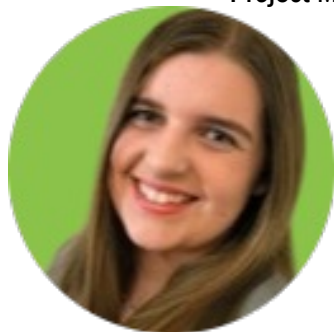
Jamie Meadows
Project Monitor



Jessica Clark
Business Support



Andrew Zimmerman
Program Analyst



Sophia Becker
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Frank Fields
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Anthony Sorbera
Project Monitor

Reviewer Introductions – Emerging and Supporting Technologies



Dr. Gene Petersen, Retired



Dr. Corey Leclerc,
Professor, Dean of
Engineering,
Department of Chemical
Engineering, New
Mexico Institute of
Mining and Technology



Dr. Marie-Odile Fortier, Assistant
Professor,
Department of Civil
and Environmental
Engineering and
Construction,
University of Nevada,
Las Vegas

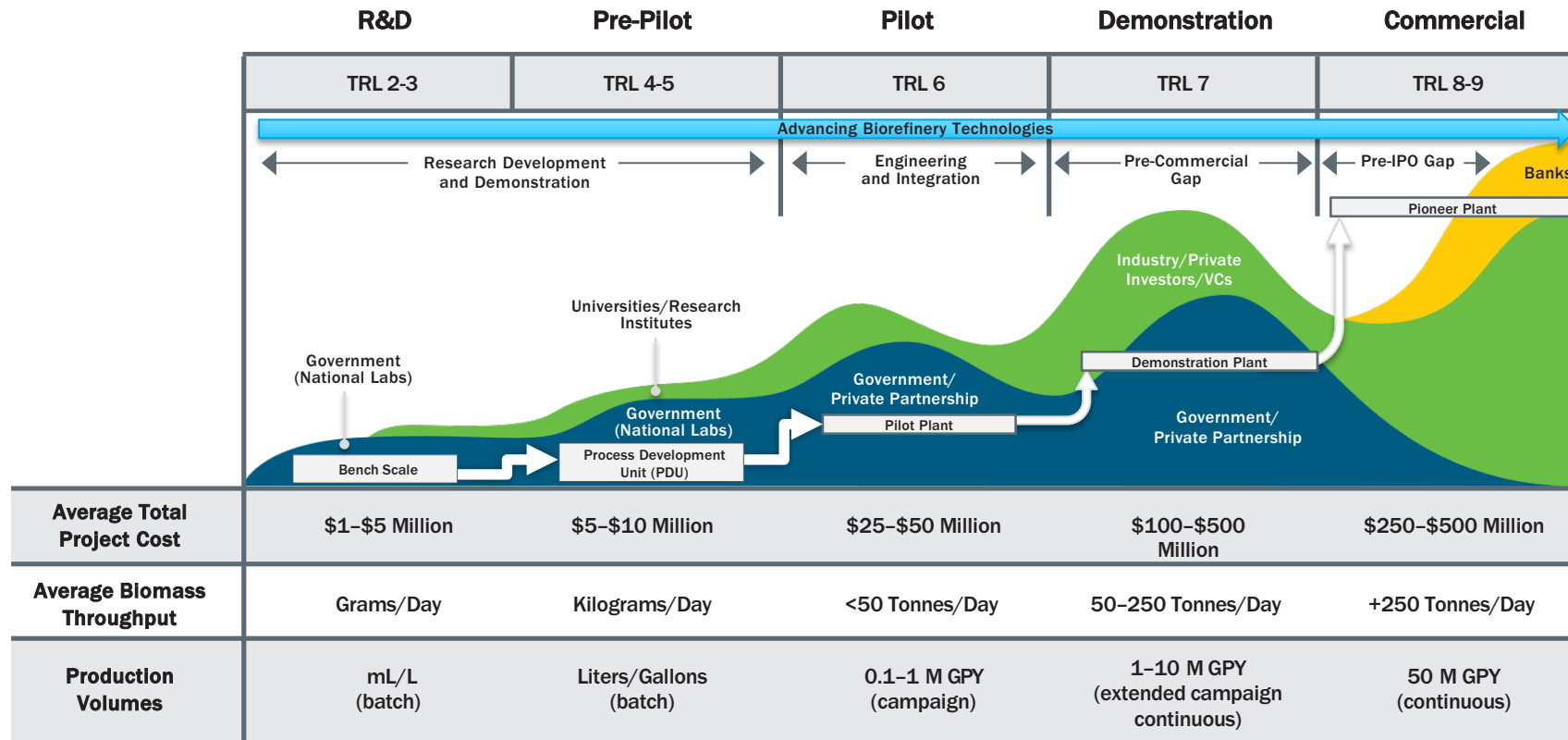


Dr. Rishi Shukla, Archer
Daniels Midland
Company



Dr. Amit Goyal,
Center of Excellence,
Hydrogen/Low
Carbon Fuels, DNV

BETO Strategy from R&D through Pioneer Refinery to Commercialization



● Government ● Project Recipients and Partners ● Banks/Bonds/Institutional Investors

SDI Strategy – Goals and Targets

- SDI directly supports BETO's strategic goal to decarbonize the transportation sector through R,D, &D to produce cost-effective, sustainable aviation and other strategic fuels
 - By 2030, SDI aims to support scale-up of multiple biofuel production pathways with a focus on sustainable aviation fuels capable of >70% GHG reduction by enabling the construction and operation of at least 4 demonstration-scale integrated biorefineries

At least 4 demo-scale IBRs producing SAF and other strategic fuels

SDI Strategy

Strategic Goal: *Enable the construction and operation of at least 4 demonstration-scale integrated biorefineries producing SAF and other hard-to-decarbonize transportation fuels (marine, rail) at >70% GHG reduction*

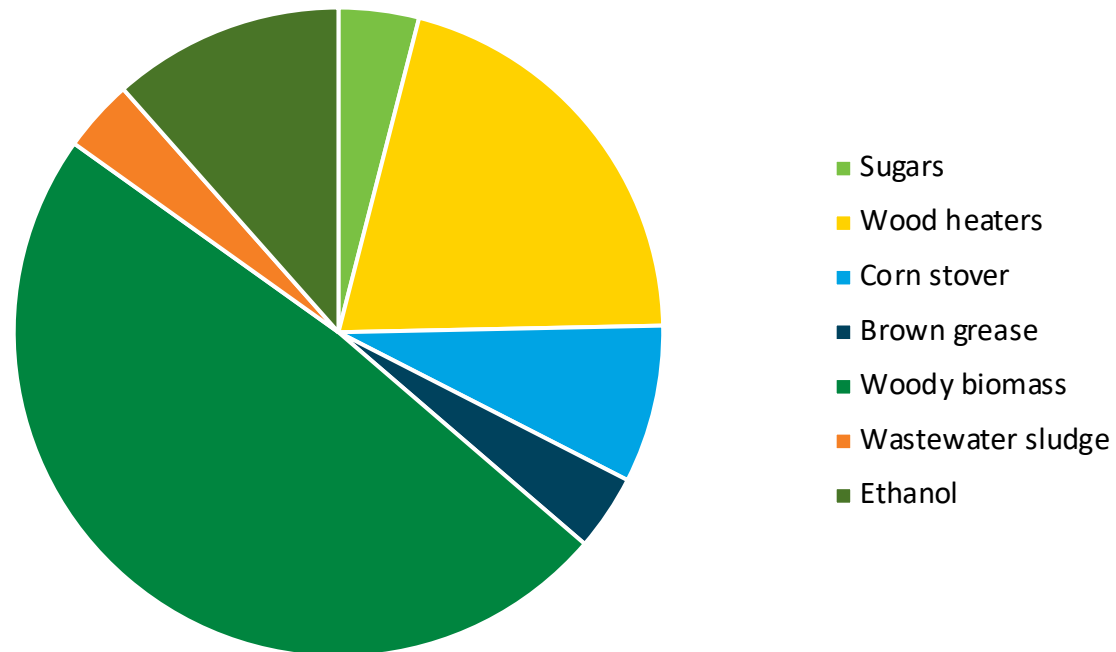
Approaches:

- Selecting **“pre-pilot” scale projects that focus on critical unit operation priorities** brought forth by industry partners, National Labs, or other BETO subprograms
- Encouraging use of **modeling, of unit operations or key integrations**
- Providing **feedback loops to BETO’s other R&D subprograms**
- Conducting feasibility studies and demonstrating technologies to significantly **reduce GHG emissions from first generation ethanol facilities**
- Prioritizing investments to demonstrate production using the 7 ASTM **approved SAF pathways** and **enabling ASTM approval** of new SAF routes in development
- Supporting R&D into **possible fuel improvements for SAF** such as molecules that reduce contrail formation, reduce emissions, or deliver higher energy densities
- Collaborating with interagency and international partners to investigate fuels for **maritime sector**
- Conducting technoeconomic feasibility studies on liquid biofuels for U.S. **freight rail**
- Engaging with **policymakers and industry stakeholders** to facilitate joint planning and investment in biofuel production and supporting infrastructure

SDI Strategy – Approach

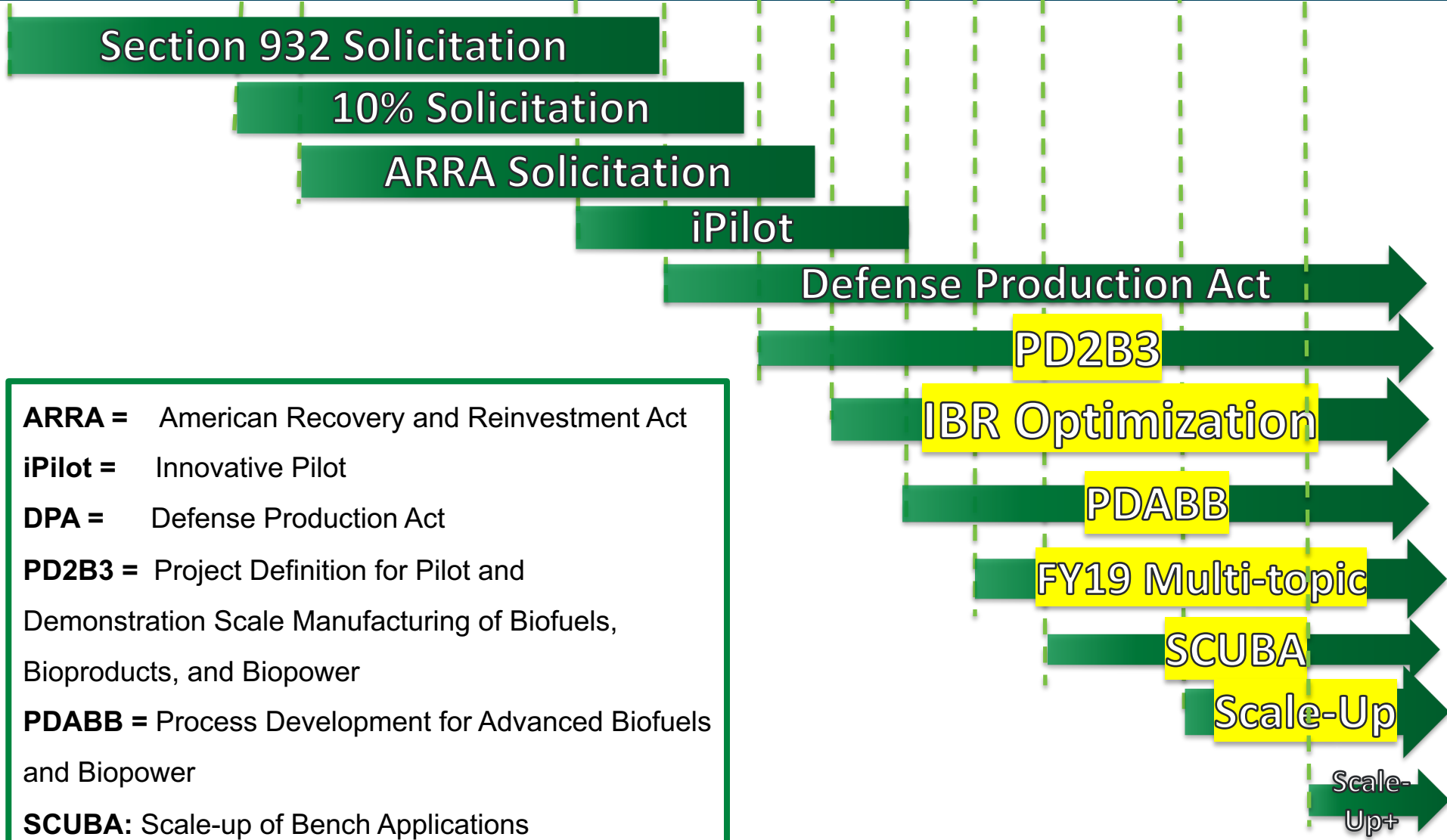
- \$62 million Federal funding will be presented here in the SUP session
 - Majority of funding is tech using woody biomass

Federal budget, SDI projects presenting in SDI-SUP

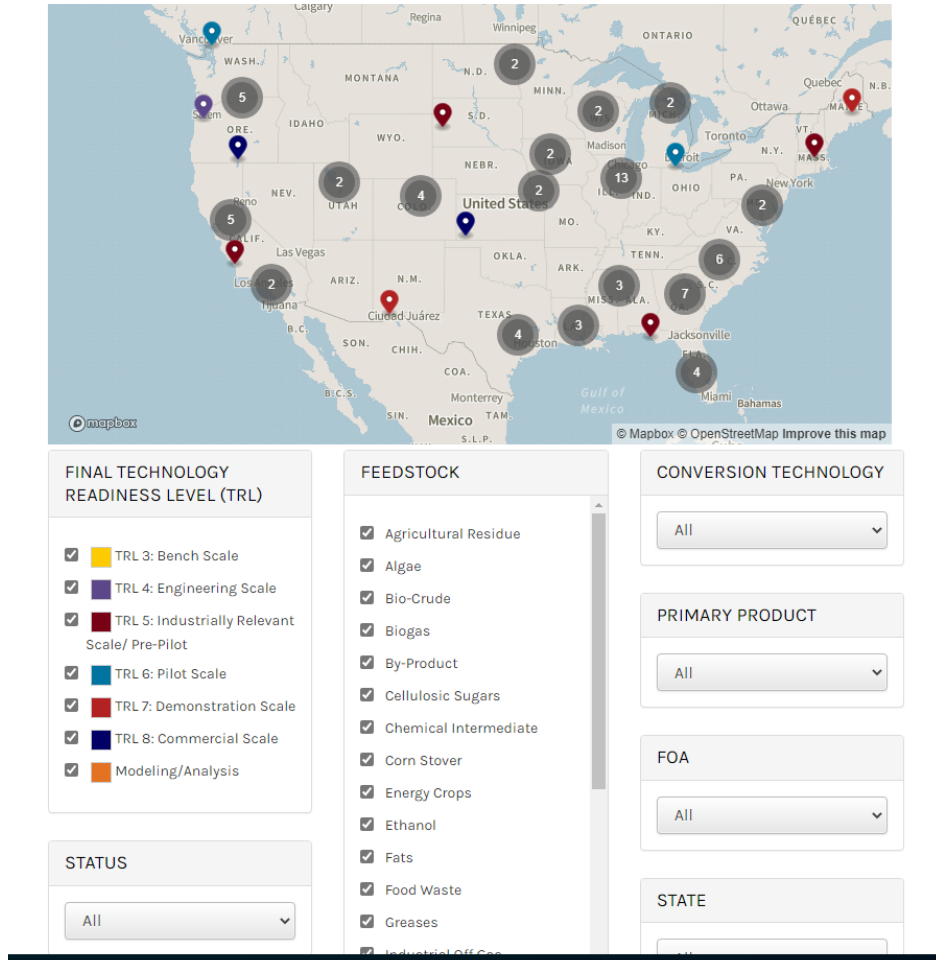


SDI Program FOA History

2006 2008 2010 2012 2014 2016 2018 2020 2021 2022



SDI Program FOA History

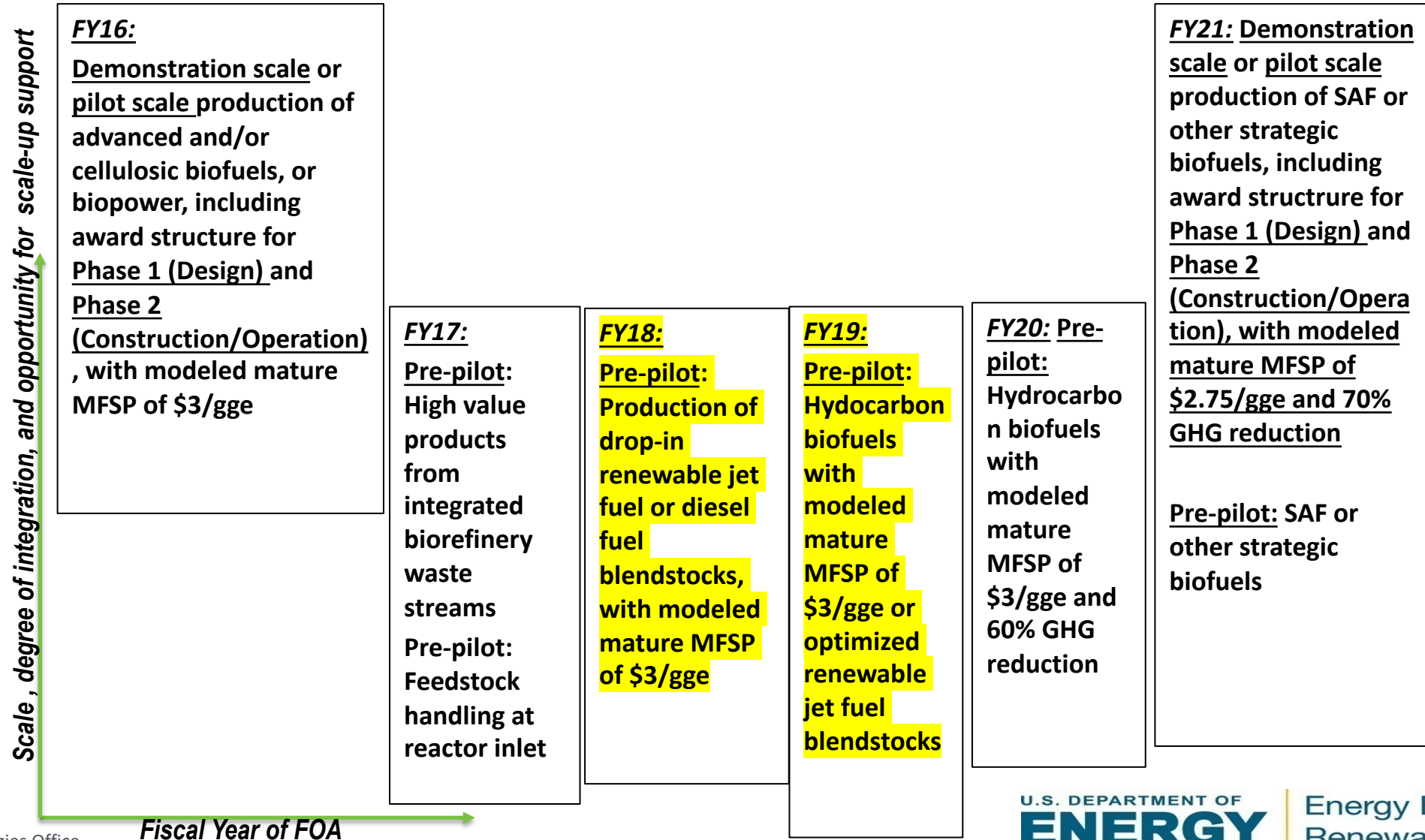


Final
Technical
Reports



<https://www.energy.gov/eere/bioenergy/integrated-biorefineries>

SDI Strategy - FOA approach of projects at Peer Review



Residential Wood Heat

- Congressional appropriations from FY19 to present "**\$5,000,000** is to support development and testing of new domestic manufactured low-emission, high efficiency, residential wood heaters"
- 3 FOA's have been offered FY19-FY21
 - DE-FOA-0002029: FY19 BETO Multi-Topic Funding Opportunity Announcement
 - DE-FOA-0002203 - FY20 Bioenergy Technologies FOA
 - DE-FOA-0002396 – FY21 BETO Scale-up and Conversion FOA
- Objectives
 - Design to improve clean combustion
 - Automation
 - Power Generation
 - Catalyst Development
 - Retrofit devices

- FY18 – Process Development for Advanced Biofuels and Biopower (PDABB): DE-FOA-0001926
 - Topic Area 1: Drop-In Renewable Jet Fuel Blendstocks (Technology Holding; Applied Research Associates; Washington State University)
 - Minimum of **1 dry metric ton per day (pilot-scale)**
 - Development of drop-in renewable jet blendstocks with high specific energy, price competitiveness, and acceptability by certification organizations such as ASTM
 - Must produce and test at least 100 gallons of renewable jet fuel

Presenting today in this session

FY19 FOA

- FY19 – BETO Multi-Topic FOA: DE-FOA-0002029
 - AOI 5: Optimization of Bio-Derived Jet Fuel Blend (University of Colorado; Vertimass; Purdue University)
 - Jet fuel with at least 4% net increase in energy content, with minimal aromatics without compromising seal swell requirement for O-rings
 - 2 gallons produced with ASTM tests for fuel suitability and operability

Presenting today in this session

Agenda Overview – EAST Monday afternoon

- *Pre-pilots: Optimized jet fuel and drop-in jet fuel*

Start Time	End Time	WBS #	Title	Organization	Speaker	FOA
1:00 PM	1:30 PM		Technology Area Introduction - SDI	BETO	SDI Session Lead	
1:30 PM	2:00 PM	3.5.1.410	Cellulosic-Derived Advantage Jet Fuel	University of Colorado	J. Will Medlin	FY19 Pre-pilot - Optimized jet fuel
2:00 PM	2:30 PM	3.5.1.412	Production of renewable cycloalkanes from ethanol for blending with jet fuel to enhance energy density and material compatibility and reduce particulate emissions	Vertimass	John Hannon	FY19 Pre-pilot - Optimized jet fuel
2:30 PM	3:00 PM	3.5.1.408	Higher energy-content jet blending components derived from ethanol	Purdue University	Gozdem Kilaz	FY19 Pre-pilot - Optimized jet fuel
3:00 PM	3:20 PM		<i>Break</i>	<i>All</i>		
3:20 PM	3:50 PM	3.5.1.401	Novel Method for Biomass Conversion to Renewable Jet Fuel Blend	Technology Holding	Mukund Karanjikar	FY18 Pre-pilot - drop-in jet fuel
3:50 PM	4:20 PM	3.5.1.404	Drop-in Renewable Jet Fuel from Brown Grease via the Biofuels ISOCONVERSION Process	Applied Research Associates	Jeff Rine	FY18 Pre-pilot - drop-in jet fuel
4:20 PM	4:50 PM	3.5.1.402	Hybrid HEFA-HDCJ Process for the Production of Jet Fuel Blendstocks	Washington State University	Manuel Garcia-Perez	FY18 Pre-pilot - drop-in jet fuel
4:50 PM	5:30 PM		<i>Closed Door Comment Review Session</i>	<i>Reviewers</i>		

Agenda Overview – EAST Tuesday morning

- *Sunsetting and continuing pre-pilots, mostly direct liquefaction.*

Start Time	End Time	WBS #	Title	Organization	Speaker	FOA
8:00 AM	8:30 AM		<i>Registration, Breakfast</i>	<i>All</i>		
8:30 AM	8:45 AM		Technology Area Daily Intro	BETO		
8:45 AM	9:15 AM	3.1.1.010	Virtual engineering of low-temperature conversion	NREL	Ethan Young	AOP
9:15 AM	9:45 AM	3.1.1.002	Improved biomass feedstock materials handling and feeding engineering data sets, design methods, and modeling/simulation tools	Forest Concepts	Christopher Lanning	FY17 Pre-pilot - IBR feeding systems
9:45 AM	10:15 AM	3.5.1.304	Agricultural and Woody Biomass to Diesel Fuel with FT Intermediate	West Biofuels	Matthew Summers	FY18 Pre-pilot - drop-in diesel fuel
10:15 AM	10:30 AM		<i>Break</i>	<i>All</i>		
10:30 AM	11:00 AM	3.5.1.601	Nearcritical Fluids Treatment for Liquefaction and Extraction of Bio-Fuels	University of Maryland	Ashwani Gupta	FY21 Pre-pilot
11:00 AM	11:30 AM	3.7.3.005	Scaling Up Biocrude Derived Anode Material (BDAM)	North Carolina State University	Sunkyu Park	FY20 Pre-pilot - ScUBA
11:30 AM	12:00 PM	3.5.1.301	Bio-crude Production and Upgrading to Renewable Diesel	Research Triangle Institute	Dave Dayton	FY18 Pre-pilot - drop-in diesel fuel
12:00 PM	1:00 PM		<i>Lunch</i>	<i>All</i>		

Agenda Overview – EAST Tuesday afternoon

- *Sunsetting and continuing pre-pilots, and end uses*

Start Time	End Time	WBS #	Title	Organization	Speaker	FOA
1:00 PM	1:30 PM	3.4.3.504	Microchannel Reactor for Ethanol to n-Butene Conversion	Oregon State University	Brian Paul	FY20 Pre-pilot - ScUBA
1:30 PM	2:00 PM	3.5.1.204	Integrated Reactive Catalytic Fast Pyrolysis System for Advanced Hydrocarbon Biofuels	Research Triangle Institute	Dave Dayton	FY19 Pre-pilot - Systems Reserch for Hydrocarbon Biofuels
2:00 PM	2:30 PM	3.4.3.305	Integrated Separations to Improve Biocrude Recovery for Biofuels and Bioproducts	Research Triangle Institute	Dave Dayton	FY20 Pre-pilot - ScUBA
2:30 PM	3:00 PM	3.4.3.306	Bio Oil Co Processing with Refinery Streams - PNNL, NREL, LANL	NREL	Reinhard Seiser	AOP
<i>3:00 PM</i>	<i>3:20 PM</i>		<i>Break</i>	<i>All</i>		
3:20 PM	4:05 PM	3.1.4.014	Advancing the Development of Biofuels for the Maritime Sector – ORNL, NREL, PNNL, ANL	ORNL	Michael Kass	AOP
4:05 PM	4:35 PM	3.5.1.501	Multi-stream Integrated Biorefinery Enabled by Waste Processing	Texas A&M Agrilife Research	Susie Dai	FY17 Pre-pilot - IBR co-products
<i>4:35pm</i>	<i>5:15pm</i>		<i>Closed Door Comment Review Session</i>	<i>Reviewers</i>		

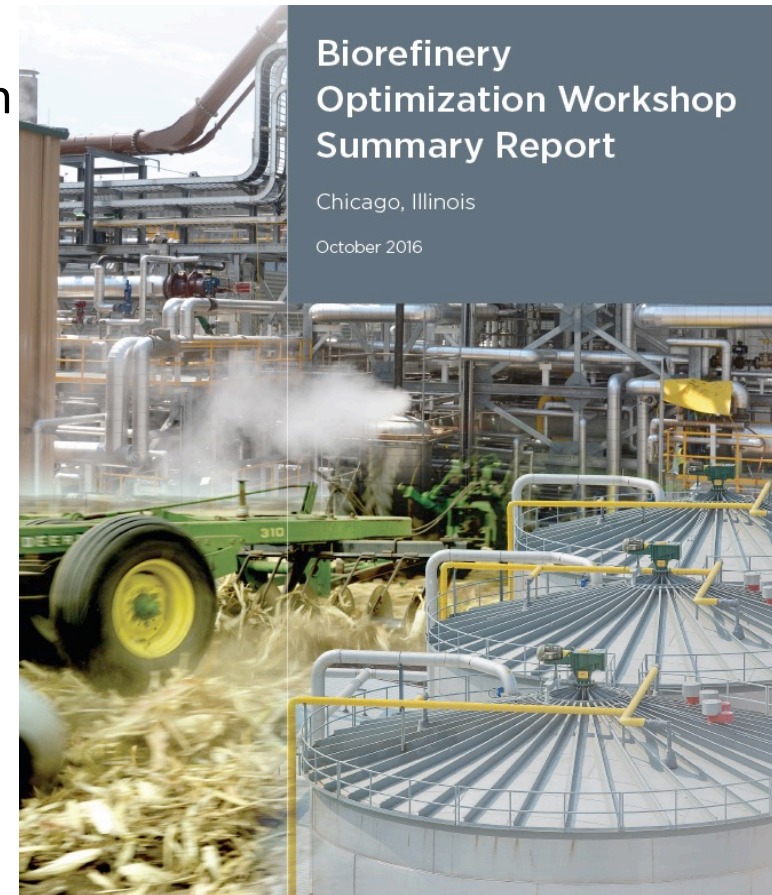
Agenda Overview – EAST Wednesday

- *Wood heaters*

8:00 AM	8:30 AM		<i>Registration, Breakfast</i>	<i>All</i>		
8:30 AM	8:45 AM		Technology Area Daily Intro	BETO		
8:45 AM	9:15 AM	5.5.1.105	Advancing wood heater evaluation methodology for accelerating innovation - LBNL, BNL	BNL	Rebecca Trojanowski	AOP
9:15 AM	9:45 AM	5.5.1.102	Automated Wood Stove UFEC23	ISB Marketing	Guillaume Thibodeau-Fortin	FY19 Wood Heater
9:45 AM	10:15 AM	5.5.1.101	Swirl Stove: Swirling combustion for efficient wood burning	MF Fire	Paul LaPorte	FY19 Wood Heater
10:15 AM	10:30 AM		<i>Break</i>	<i>All</i>		
10:30 AM	11:00 AM	5.5.1.103	Fire MAPS - Secure Performance Monitoring and User Alerts System (for wood burning stoves)	MF Fire	Paul LaPorte	FY19 Wood Heater
11:00 AM	11:30 AM	5.5.1.106	Development of Forced-Air Combustion Systems with Automated Controls to Reduce Emissions from Cordwood Room Heaters in Everyday Use	Oregon State University	Nordica MacCarty	FY21 Wood heater
11:30 AM	12:00 PM	5.5.1.107	Clean Combustion Technology with Efficient and Autonomous Wood Heater Operation over the Full Cycle	The University of Alabama	Ajay Agrawal	FY21 Wood Heater
12:00 PM	1:00 PM		<i>Lunch</i>	<i>All</i>		
1:00 PM	1:30 PM	3.5.2.605	Simulation-Driven Design Optimization and Automation for Cordwood-Fueled Room Heaters	Ohio State University	Shawn Midlam-Mohler	FY20 Wood Heater
1:30 PM	2:00 PM	3.5.2.604	Advanced Low-Emission Residential Fluid-Bed Biomass Combustor	NTRE Tech	Bartev Sakadjian	FY20 Wood Heater
2:00 PM	2:40 PM		<i>Closed Door Comment Review Session</i>	<i>Reviewers</i>		

SDI Strategy – Engagement through Workshops

- SDI-EAST will hear from 2 projects (Forest Concepts and Texas A&M AgriLife Research) from the FY17 FOA, which was designed with input from a 2016 workshop
 - Feedstock and solid materials handling
 - Co-product and waste stream monetization



SDI Strategy – Engagement through RFIs

- SDI-EAST will hear several projects from an organization (Research Triangle Institute) that responded to the FY16 RFI on Biofuels and Bioproducts Process Pilot Verification Capabilities






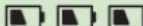
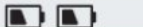


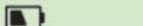








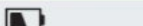


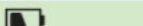



<https://www.energy.gov/eere/bioenergy/articles/biofuels-and-bioproducts-process-pilot-verification-capabilities-rfi>

SDI Strategy – Engagement through Advisory Boards

- Multi-lab AOP projects utilize Advisory Boards
 - **Advanced the Development of Biofuels for the Marine Sector – ORNL, NREL, PNNL, ANL**
 - External Advisory Board of 4 energy companies, 2 industry experts, 3 shipping/engine companies, 4 government/professional/trade/nonprofits, 1 shipping port/terminal, and 5 biofuel companies
 - **Bio-oil Co-processing with Refinery Streams – NREL, PNNL, LANL**
 - Industrial Advisory Board of 8 energy companies, 1 biofuel company, 4 catalyst companies, 2 government policy agencies, and 2 universities

SDI Progress in addressing Transportation Decarbonization

- The multi-agency U.S. National Blueprint for Transportation Decarbonization clearly scoped the best long-term opportunities for biofuels

	 BATTERY/ELECTRIC	 HYDROGEN	 SUSTAINABLE LIQUID FUELS
Light Duty Vehicles (49%)*		—	TBD
Medium, Short-Haul Heavy Trucks & Buses (~14%)			
Long-Haul Heavy Trucks (~7%)			
Off-road (10%)			
Rail (2%)			
Maritime (3%)		 *	
Aviation (11%)			
Pipelines (4%)		TBD	TBD
Additional Opportunities	<ul style="list-style-type: none"> Stationary battery use Grid support (managed EV charging) 	<ul style="list-style-type: none"> Heavy industries Grid support Feedstock for chemicals and fuels 	<ul style="list-style-type: none"> Decarbonize plastics/chemicals Bio-products
RD&D Priorities	<ul style="list-style-type: none"> National battery strategy Charging infrastructure Grid integration Battery recycling 	<ul style="list-style-type: none"> Electrolyzer costs Fuel cell durability and cost Clean hydrogen infrastructure 	<ul style="list-style-type: none"> Multiple cost-effective drop-in sustainable fuels Reduce ethanol carbon intensity Bioenergy scale-up

* All emissions shares are for 2019

* Includes hydrogen for ammonia and methanol

Figure B. Summary of vehicle improvement strategies and technology solutions for different travel modes that are needed to reach a net-zero economy in 2050 (more details provided in Section 5).

<https://www.energy.gov/eere/us-national-blueprint-transportation-decarbonization-joint-strategy-transform-transportation>

SDI Strategy – SAF

- Sustainable Aviation Fuel (SAF) Grand Challenge
 - Government-wide effort for enabling SAF

2030: 3 billion gallons per year SAF
2050: ~35 billion gallons per year SAF



<https://www.energy.gov/eere/bioenergy/articles/sustainable-aviation-fuel-grand-challenge-roadmap-flight-plan-sustainable>

SDI Progress - Maritime Fuels

- Maritime transport is 1% of U.S. GHG emissions and rising globally
- Hard to electrify **>8 billion GGE fuels used in the U.S. maritime sector**
- Tuesday afternoon in the SDI-EAST session, you will hear from the AOP “Advancing the Development of Biofuels for the Maritime Sector – ORNL, NREL, PNNL, ANL”



- BETO participating in Mission Innovation: Zero-Emissions Shipping
 - Goal: at least 5% of the global deep-sea fleet capable of running on zero-emission fuels by 2030
- FY22 Scale-Up+ FOA selections included maritime biofuels project

SDI Progress – Freight Rail

- Renewable diesel and biodiesel considered near-term solutions for decarbonizing freight rail
- SDI started funding a new AOP “Rail Feasibility Study – ANL, ORNL, PNNL”
 - The outcome of the project will be a report assessing different biofuels types as near-term bioenergy solutions for freight rail
- SDI discussions with rail agency
- SDI interfacing with VTO’s new Decarbonization of Off-road, Rail, Marine, and Aviation program
- 4 billion GGE diesel fuel used in rail transportation in the U.S.
 - <https://afdc.energy.gov/data/10661>

Legacy locomotive diesel in the freight rail fleet will remain for decades

SDI Progress - Descoping Biofuels R&D for Cars and Trucks

- In light of shifts in market, policy, and funding, DOE ended the Co-Optimization of Fuels & Engines (Co-Optima) after 6 years of support from Vehicle Technologies Office and BETO

Major Foundational Discoveries and Impacts of Co-Optima

Established central engine and fuel hypotheses to guide research activity

Developed engine efficiency merit function for turbocharge Spark Ignition combustion

Evaluated thousands of molecules and mixtures through tiered screening to identify 10-15 most promising blendstocks each for diesel and gasoline fuels

Advanced understanding of chemical kinetics, particular their effects on autoignition and soot formation

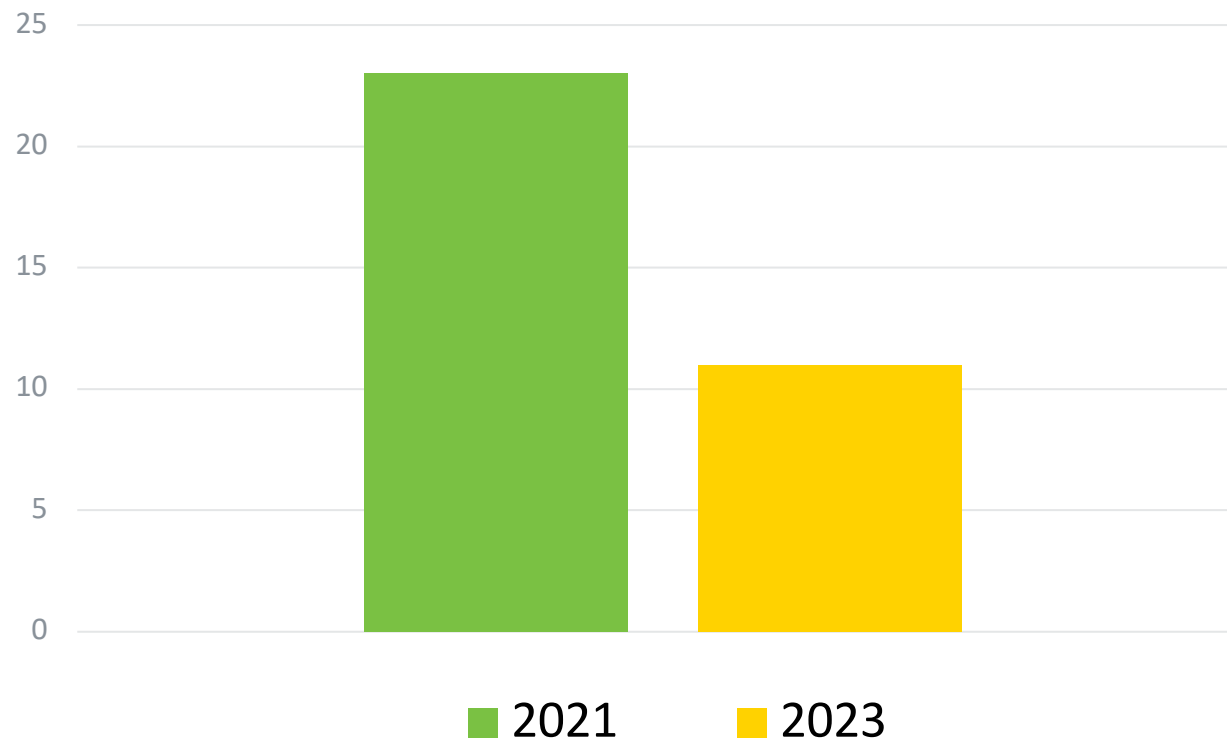
Uncovered new insights into fuel molecular structure-property relationships to predict fuel properties and identify new blendstock candidates

Assessed interplay of candidate blendstocks with multiple combustion approaches

SDI Progress - Active Management

- SDI's FOA/AOP funding proportion has shifted more and more to FOAs
- FOAs use language encouraging cooperation with National Labs

Number of National Lab AOPs in SDI portfolio



Former Conversion FOA projects, with their tech now in SDI FOA projects presenting this week

2011

2013

2015

2017

2019

2021

FY11 Conversion FOA “Catalytic Upgrading of Thermochemical Intermediates”
-Virent
-Research Triangle Institute
-LanzaTech

FY18, 19, 20 SDI: Research Triangle Institute

FY16, FY18 SDI: LanzaTech

FY19 SDI: University of Colorado (w/ Virent)

FY12 Conversion FOA “Innovative Biosynthetic Pathways to Advance Biofuels”
-Novozymes
-Texas A&M University

FY12 Conversion FOA “Bio-oil Stabilization and Commodization”
-Gas Technology Institute

FY21 SDI: D3Max (w/ Novozymes)

FY17 SDI: Texas A&M AgriLife Research

FY14 Conversion FOA “Biological and Chemical Upgrading for Advanced Biofuels and Products”
-Vertimass
-Texas A&M University
-American Process Inc.

FY19 SDI: Gas Technology Institute

FY19 SDI: Vertimass

FY16 SDI: AVAPCO

Room Rules

- 20-minute presentations (one exception for a four-lab AOP)
- 10 minutes Q&A
 - Lead Reviewer first, then open to all of Review panel, then open to general audience
- We must stay on time