

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

2023 BETO Peer Review

Conversion R&D Overview



Conversion R&D Team – DOE



Kevin Craig



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Conversion R&D Team – Support Team



Jessica Phillips Technical Project Monitor, BGS Team Lead



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Conversion Agenda At-A-Glance (8 of 14 Sessions)



ENERGY

Renewable Energy

Program Structure



ENERGY

Renewable Energy

Program Structure





Program Structure x MYPP Platforms





Bio-Optimized Technologies to keep Thermoplastics out of Landfills and the Environment (BOTTLE™)



Vision

• Deliver scalable technologies that enable costeffective recycling, upcycling, and energy efficiency for plastics

Mission

- Develop robust processes to upcycle existing waste plastics, and
- Develop new plastics and processes that are recyclable-by-design

Goals

- Work with industry to catalyze new upcycling paradigms and novel feedstocks
- Leverage DOE investments in process development, catalysis, materials, and analysis- driven R&D

Joint Funded with the Advanced Materials and Manufacturing Office



ENER

Renewable Energy

Conversion R&D Program Goal

Strategic Goal: decarbonize the U.S. economy by developing efficient and economical biological and chemical technologies to convert renewable carbon resources into bioenergy and renewable chemicals and materials.

R&D to:

- Lower the cost of fuels and products
 - Carbon efficiency
 - Improved yield and selectivity
 - "Catalyst" lifetime
 - Separations and process intensification
 - Novel unit operations/reactors
- Improve environmental performance and DEI impact
 - Reduce process energy, emissions, and water use
 - Efficient use of "waste" and residues
 - Locally and regionally appropriate technologies



Challenges



Budget totals for years under review



Industry Academic

Lab

Annual Conversion R&D Budget (\$M)



Funding Distribution



Industry Academic Lab



- AOPs direct Lab funding
 - 3-year projects
 - Externally reviewed
- DFOs/CRADA-calls/CRADA-lites \$60.0 \$50.0
 - Lab/Industry partnerships
 - Transitional TRL
 - Competitive
 - ABF, CCB, CCPC, SepCon
- Funding Opportunities (FOAs)
 - Competitive
 - Industry, Universities, Labs



Reviewed Project Budgets (\$M)



Recent Funding Opportunity Announcements



2020

Waste to Energy Strategies for the Bioeconomy:
Municipal Solid Waste (MSW)
Optimizing Community Scale Wet Organic Wastes

Biopower and Products from Urban and Suburban Wastes: North American Multi University Partnership for Research and Education:

- Biopower from Organic
 Wastes
- Waste Plastics to Products

Scalable CO2 Electrocatalysis

Polymer Re/Upcycling*

- Highly recyclable or biodegradable plastic
- Deconstruct and upcycle existing plastic
- BOTTLE collaborations

*Joint FOA with AMO/AMMTO



Affordable, Clean Cellulosic Sugars for High Yield Conversion

> Separations to Enable Biomass Conversion

- Separations to Enable Biomass Conversion
- Separations to Enable Biomass Conversion
 (Bioprocessing Separations Consortium)

Renewable Natural Gas (RNG)
Research & Development

• Pilot scale



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Robust Microbial Cells

Robust Catalytic Processes

Community Scale Resource and Energy Recovery from Organic Wastes



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Overcoming Barriers to Syngas Conversion



Key Accomplishments

Catalytic Upgrading

- Single-step oligomerization of mixed olefins to jet fuel range was successfully demonstrated at >90% single pass conversion and >75% selectivity (Fri 2:30pm)
- Identified improvements to TEA and LCA of the Catalytic Upgrading of Biochemical Intermediates projects (Thu 1:30pm).
- Direct Funding Awards with Sironix, Visolis, and Twelve were completed (Thu 3:50pm, Fri 9:45am, 2:00pm).
- The Catalyst Property Database (CPD) opened for community data addition, an increase of 300% in data volume (DataHub, Thu 1:00pm).
- Identified Catalytic Fast Pyrolysis-oil compounds that cause plugging during hydrotreating and generated a cycloalkane-rich SAF product that **meets key ASTM D4054 specs** (CUPP, Thurs 3:20 pm)
- Improved catalyst design and regeneration procedures for multiple catalytic technology pathways through collaborative catalyst characterization and synthesis efforts (ACSC, Fri 10:30am)
- Identified overarching catalyst stability challenges related to bioenergy (Catalyst Deactivation, Fri 11:15am)
- Accelerating process scale up through development of state-of-the-art models for process and catalyst optimization (CCPC, Fri 1:00 pm)



















TOPSOE









forestconcepts

Key Accomplishments (Continued)

- Lignin Valorization
 - A monomer yield of 77 wt% bio-available aromatic monomers from lignin was achieved via autoxidation of HDO lignin oil: the high ever reported (Lignin U... Thurs 2pm)
 - Development of **lignin analytics** method for tracking lignin in the biorefinery (*Lignin U..., Thurs 2pm*)
 - Established Memoranda of Understanding (MOU) with two scale-up partners (VITO, ExxonMobil) (LigFirst... Thurs 1pm)



- CO2 Utilization:
 - A Membrane Electrode Assemblies (MEA) electrolyzer of 1000 cm2 has been built and is being tested and optimized for CO2 utilization.
- Stood up the CO₂ Reduction and Upgrading for E-fuels Consortium.
 - Produced a **CO2-to-fuels Strategic Plan**, outlining the main R&D barriers as well as technical and scale targets that should be achieved to make an impact by 2050.
 - Integrated the existing and new projects to a united objective: develop technologies to upgrade CO₂ to fuels and chemicals to reduce GHG emissions and other environmental impacts to accelerate the decarbonization of our economy



Commercializing CO₂-based Fuels and Chemicals by 2050: R&D Gaps and Opportunities in the Direct Electrification of CO₂ Conversion (Publication Pending)

R. Gary Grim, Jack Ferrell, Zhe Huang, Ling Tao, Mike Resch National Renewable Energy Laboratory

Key Accomplishments (Continued)

- Biochemical Conversion
 - In collaboration with EPA and NIST, developed and received approval for a new analytical method allowing for cellulosic D3 RIN from corn fiber (Analytical development and support, Thurs 11:15 am)
 - Demonstrated cell-free biosynthesis approaches that can **recycle cofactors** and reducing equivalents (Cell-free and immobilization technologies... Fri 11:30 am)
 - Achieved iso-butanol product titers of > 250 g/L using a **cell-free biosynthesis system** (*Towards economic cell-free isobutanol... Fri 1:00 pm*)
 - Validated in-situ product recovery approach for the production of organic acids (Biological upgrading..., Fri 10:30 am)







Guidance on Qualifying an Analytical Method for Determining the Cellulosic Converted Fraction of Corn Kernel Fiber

This updated 2022 guidance benefits from recent scientific advancements, including work conducted by the Department of Energy's (DOE) National Renewable Energy Laboratory (NREL), to develop a public method that addresses the analytical concerns identified in the 2019 guidance.







U.S. DEPARTMENT OF ENERGY OFFICE OF ENERGY EFFICIENCY & RENEWABLE ENERGY

Key Accomplishments (Continued)



Strategy for Plastics Innovation Released

Vision

For the United States to lead the world in developing and deploying technologies that minimize plastic waste and promote energyefficient and economic plastic and bioplastic design, production, reuse, and recycling.

Objectives/Metrics

- Address end-of-life fate for >90% of plastics
- ≥50% energy savings relative to virgin material production
- Achieve ≥75% carbon utilization from waste plastics
- Develop **cost-competitive** recyclable-by-design plastic
- Design recycling strategies that mitigate ≥50% GHG emissions relative to virgin resin or plastic intermediates



Strategy for Plastics Innovation | Department of Energy

Sustainable Aviation Fuel Developments

😵 INDEPENDENT

Jet fuel produced from food waste could dramatically cut emissions, study finds

US National Renewable Energy Laboratory researchers find sustainable fuel could reduce greenhouse gas emissions up to 165 per cent

Tom Batchelor • Tuesday 16 March 2021 15:31 • 1 Comments

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Vertimass



Vertimass and World Energy Announce Technology Partnership to Advance Renewable Fuels Development and Production



Sustainable jet fuel company Alder Fuels seals investments from United, Honeywell

\equiv THE WALL STREET JOURNAL.

SUSTAINABLE BUSINESS

Microsoft, Alaska Airlines Back CO2-to-Jet-Fuel Technology

Twelve says its fuel could shrink the carbon footprint of business travel, but supply is far from commercial scale

CISION ROLLS-ROYCE AND ALDER FUELS JOIN FORCES TO FUEL THE RACE TO NET ZERO

Southwest' MEDIA

Southwest Airlines Invests in Sustainable Aviation Fuel Pilot Project Supported by The Department Of Energy

Carrier's first-of-its-kind investment supports the development of technology intended to commercialize sustainable aviation fuel



Climate change: Jet fuel from waste 'dramatically lowers' emissions

By Matt McGrath Environment correspondent

(15 March 2021)

LanzaJet Gains Altitude With Significant Project Funding

The future of sustainable aviation fuel (SAF) is even more poised for take-off thanks to a 50 million US grant from Breakthrough Energy.



First commercial flight partly fuelled by recycled waste lands in UK

Virgin Atlantic flight from Orlando to Gatwick powered by blend of jet fuel and ethanol

Bioproduct Projects (and Alums) in the News

Iowa breaks ground on first U.S. plant producing bio-BDO

May 17, 2022 / Agriculture, Biomanufacturing, State Policy / By Bio.News Staff

New joint venture unveils QIRA, a bio-based 1,4-butanediol (BDO) that saves up to 93 percent of greenhouse gas emissions compared to the use of conventional BDO



20.07.2022

Geno and Aquafil begin pre-commercial production for plant-based nylon-6

lululemon partners with Genomatica on plant-based nylon

Danimer will invest big in PHA

Predicting strong demand, the biopolymer maker plans to spend \$700 million on a new plant

NatureWorks to expand Ingeo PLA capacity

Amazon and U.S. Department of Energy team up to cut plastic waste

MANUFACTURING • EDITORS' PICK

The Rush For Hand Sanitizers Is A Boom For Hand Moisturizers. This Startup Has A Solution For Both.

John Cumbers Senior Contributor © Synthetic biology author.



WIRED

June 02, 2021 04:10 PM Plastics News

BIOBASED CHEMICAL

This Startup Is Trying to Make Juicy Steaks Out of Thin Air

Air Protein is transforming carbon dioxide into delicious cuts of meat, with the helping hand of bacteria.

Written by Amazon Staff

March 9, 2022

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Enabling Energy/Resource Recovery from Waste Partnerships

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2021

2022

Waste-to-Energy Technical Assistance for Local Governments

NREL provides U.S. local governments with technical assistance to advance waste-to-energy (WTE) technologies on behalf of the U.S. Department of Energy Bioenergy Technologies Office (BETO).





Relocating SoCalGas 700L 18-bar bioreactor system from NREL to Summit's dairy digester in Maine: will process >10% of the state's dairy manure

OW session: Thursday, 1:30 pm



Common Themes:

- Cost-benefit analysis is popular
- Municipalities want case studies
- Community champions are key
- Let communities define the problem statement

OW session: Friday, 8:45 am

• Continued emphasis on:

- SAF
- Chemicals decarbonization
- Technology deployment

Inter- and Intra-Agency coordination

- Chemicals coordination groups
 - AMMTO, IEDO, OCED, and HFTO, are SC-BER, SC BES, ARPA-E, FECM, S4, OTT, LP, and OP
- Polymers coordination group
 - EERE: AMMTO/BETO,BES, ARPA-E, BER, FECM, NNSA, S4
- FECM gasification systems
- NSF ABF
- BioMADE
- MSRDC



FIGURE 1. ENERGY-RELATED CO2 EMISSIONS BREAKDOWN BY INDUSTRIAL SUBSECTOR IN 2020, MILLION MT CO2.



Figure 3. U.S. primary energy-related CO_2 emissions by end use sector (left pie chart) and a breakout by industrial subsector (right stacked chart) in 2020.

Plastics Strategy | Engagement

Plastics Circularity Workshop June 8-9th Seattle, WA

> Email for questions: Coralie.backlund@ee.doe.gov



Energy Efficiency & Renewable Energy

Program Response to 2021 Peer Review

Clear metrics / LCA to guide R&D

Strategic partnerships / Scaleup

Balance of deployment & research – maintain pipeline

Balance of fuels & chemicals

Dissemination of research results

Robust IABs

Interagency

