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

Department of Energy's Evolving Interests in Plastic Circularity

Workshop for Plastic Circularity 2023

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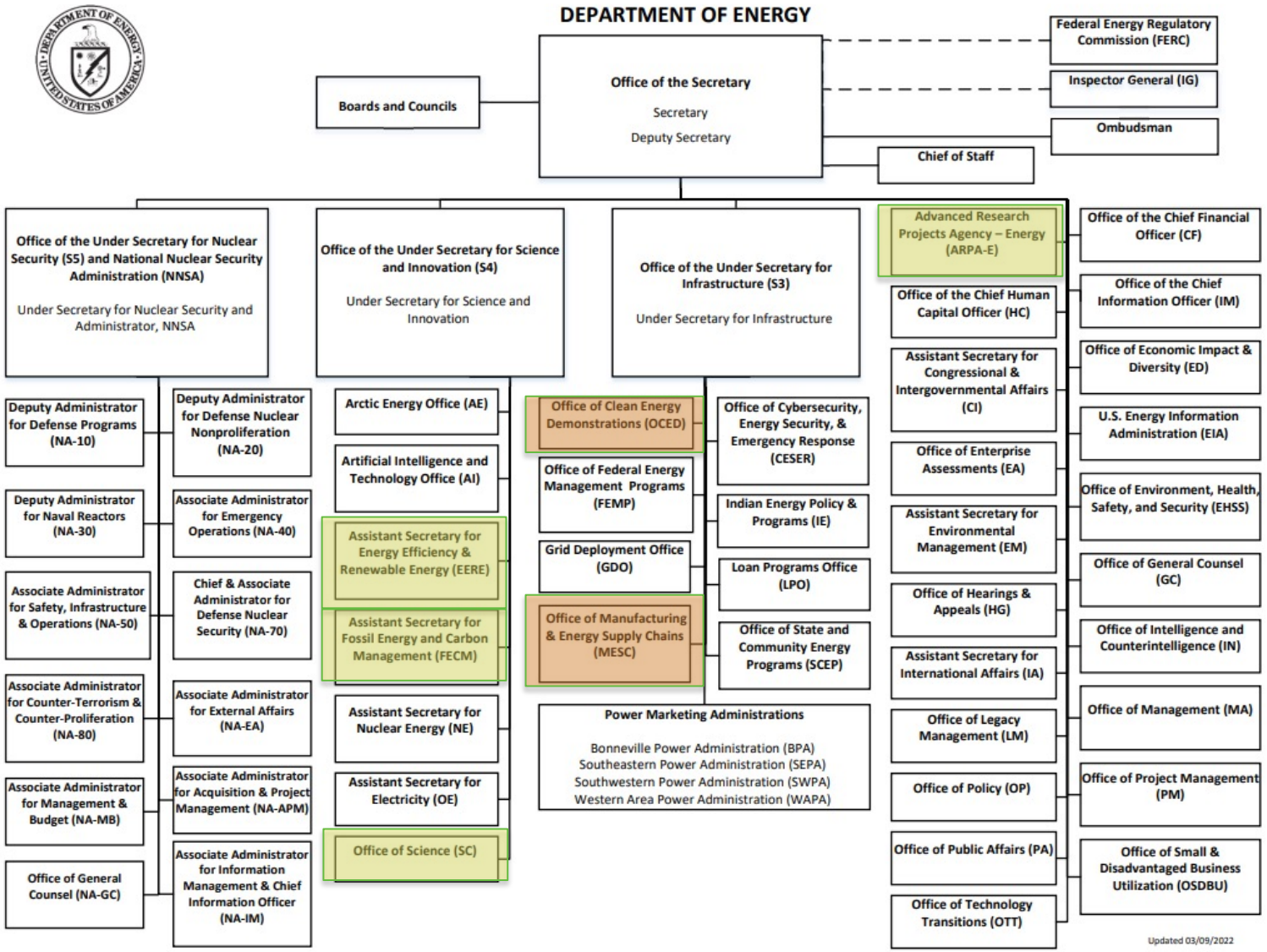
DOE Mission

The mission of the Energy Department is to ensure America's security and prosperity by **addressing its energy, environmental and nuclear challenges** through **transformative science and technology solutions**.

DOE 101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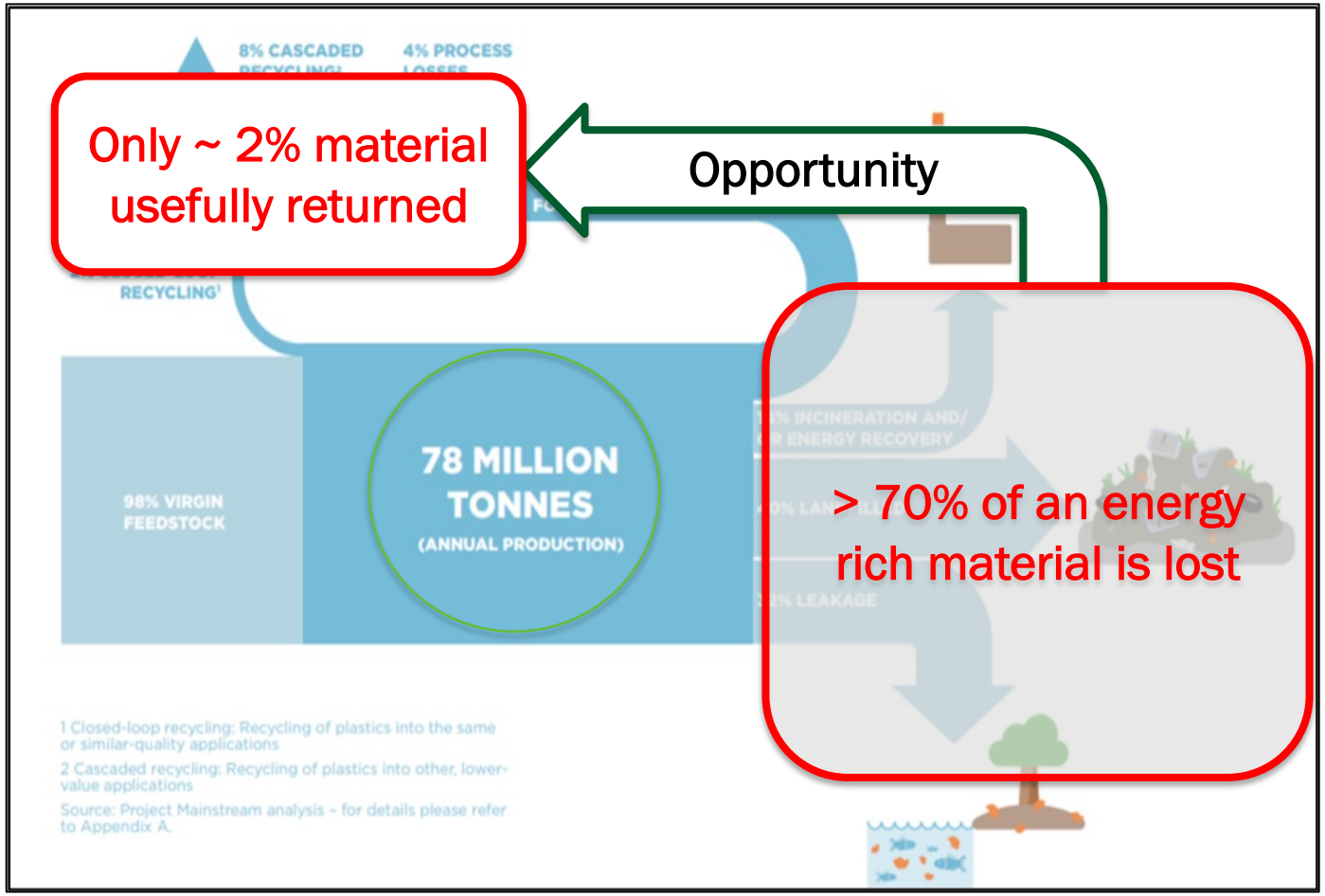
Office of Management (MA)
Office of Project Management (PM)
Office of Small & Disadvantaged Business Utilization (OSDBU)
Updated 03/09/2022

Plastic Waste: Energy and Climate Opportunity

- Plastics are made **from non-renewable feedstocks** and are increasingly accumulating[1]
- Most plastic waste ends up in landfills and the environment[2]
- **>2% of total energy consumption in the US** is used to manufacture plastics, resins, and synthetic rubber
- Production of these materials generates roughly **3% of domestic GHG emissions**
- Plastic production uses **6% of global oil production** → anticipated to be 20% by 2050[1]



Global plastic packaging production and fate[1]

1. Ellen MacArthur Foundation. 2016.
2. Geyer et al. Science Advances .2017.
3. Zheng and Suh. Nature Climate Change. 2019.

Critical to Administration Priorities

Climate

- Plastics contribute ~3% of global GHG emissions[1]
  - Improving the footprint of plastics is essential to decarbonize the industrial sector
- Recycling and making renewable plastics can reduce GHG emissions significantly[2]

Economy

- 95% of plastic waste is discarded, and the value of the material is lost[3]
- Transitioning from business as usual to green waste processing can add up to 730,000 jobs[4]

Environmental Justice

EERE is working to gain better understanding of impacts.

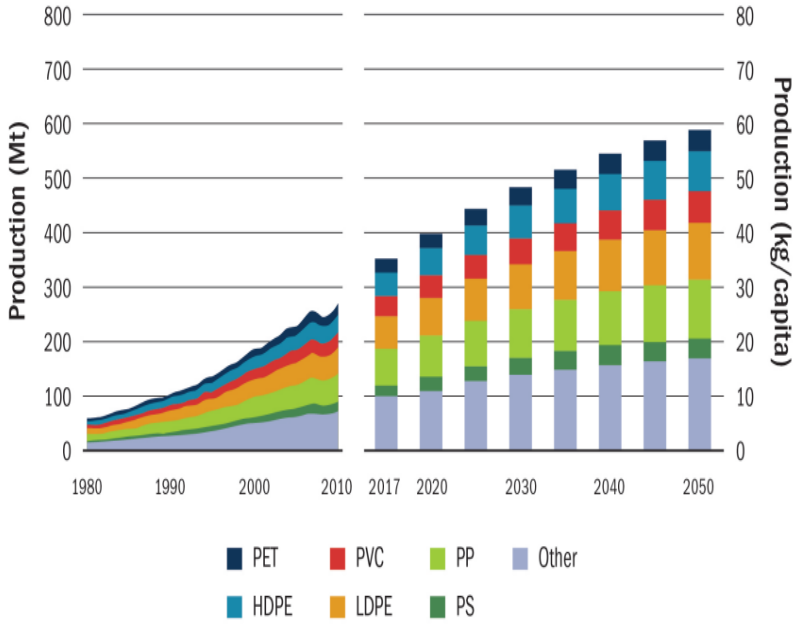
- Plastic-related GHG → climate change.[1] Effects of climate change are unequal.
- The US generates the most plastic waste of any country, and is one of the biggest coastal polluters[5]
- Net plastic exports go to developing countries[6]
- Irreversible environmental damage from plastic waste in the ocean is estimated to cost $2.5 trillion a year[7]

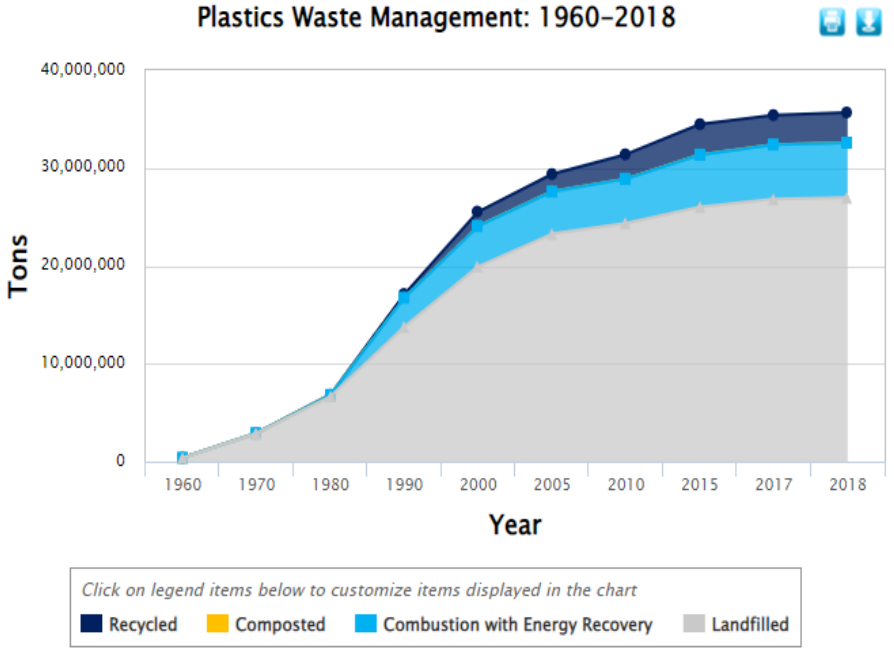
Solutions

- Recycling plastics saves >50% of GHG emissions[8]
- Making recyclable-by-design or biodegradable plastics from renewables saves GHG and energy from production to end of life[1]
- These new industries require domestic labor, providing new jobs

Recycling is Difficult and the Challenge is Growing

- Plastic waste presents many technical challenges
- Plastic production is projected to continue to increase substantially through 2050[1-2]
- Plastic recycling rates have plateaued[3]

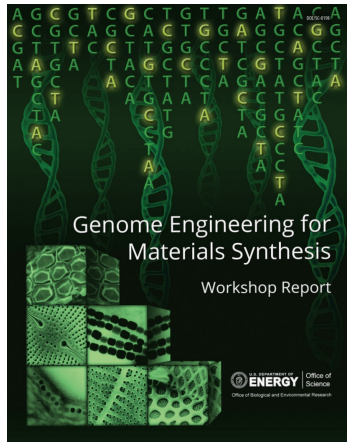




Addressing barriers to recycling can unlock greater waste reduction and energy and emissions savings

1.. International Renewable Energy Agency (IRENA). 2018. Global Energy Transformation: A Roadmap to 2015. Abu Dhabi: IRENA.; 2. International Energy Agency (IEA). 2018. The Future of Petrochemicals. Paris: IEA.; 3. https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/plastics-material-specific-data

Strategy Development



10/2018

12/2019

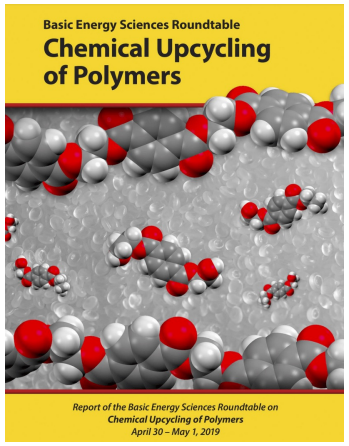
8/2020

1/2021

1/2023

2019 2020 2021 2022 2023

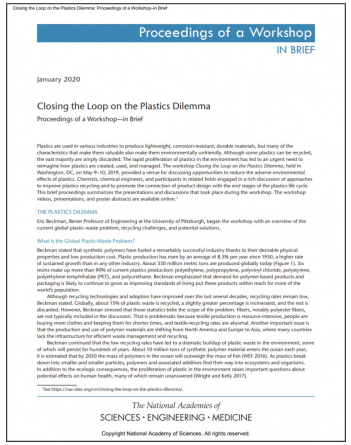
5/2019



11/2019

Plastics Innovation Challenge Launched

1/2020



11/2020

The Strategy for Plastics Innovation (SPI) has been informed by workshops and roundtables across the U.S. Department of Energy (DOE) and the federal government. Outputs from those events are listed in the following DOE and stakeholder reports.

Strategy for Plastics Innovation Objectives

Vision

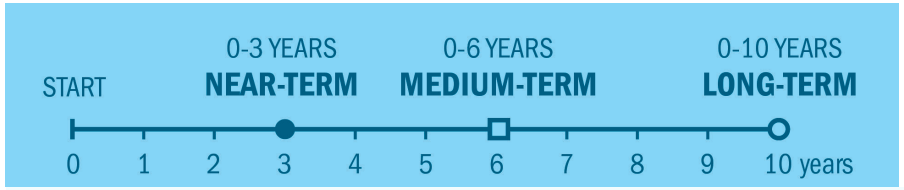
For the United States to lead the world in developing and deploying technologies that minimize plastic waste and promote energy-efficient and economic plastic and bioplastic design, production, reuse, and recycling.

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

Strategy for Plastics Innovation Goals for 2030



Deconstruction

- ● Thermal depolymerization
- □ Selective catalyst design
- ○ Biological/chemical deconstruction of mixed plastic waste

Upcycling

- ● Upcycling of easily recyclable materials
- □ Couple deconstruction with selective upcycling
- ○ Funnel deconstruction intermediates into valuable products

Recyclable by Design

- ● Organism design for novel plastic materials
- □ New chemistry for recyclable by design polymers
- ○ Multi component product recyclability

Scale and Deploy

- ● Contaminant removal and effective sorting
- □ Improve physical recycling and recovery
- ○ Advance biological systems for recycling technologies

Research Directions

SPI Goals	Challenges	Thermal Processes	Chemical Processes	Biological Processes	Physical Recycling and Recovery	Design for Circularity
Deconstruction	Retain value	●	●	●	●	●
	Feedstock heterogeneity		●	●	●	
	Contaminant removal	●	●	●	●	
	Multicomponent materials		●	●		●
Upcycling	Recover value		●	●	●	●
	New material design		●	●		●
Recyclable by Design	Design for reuse		●	●		●
	Compatibility with recycling infrastructure	●	●	●	●	●
Scale and Deploy	Life cycle assessment implications	●	●	●	●	●
	Management of distributed resource	●	●	●	●	●
	Circularity	●	●	●	●	●
	Scale of plastics challenge	●	●	●		●

Recent DOE Funding Opportunities

www.energy.gov/strategy-for-plastics-innovation

Opportunity Type	Office	Name and FY	TRL	Topic
Funding Opportunity Announcements	BES	FY2020: Energy Frontier Research Centers (EFRCs)	1-2	Center for Plastics Innovation; Institute for Cooperative Upcycling of Plastics
	BES	FY2021: Chemical Upcycling of Polymers	1-2	Chemical Upcycling
	BES	FY22: Chemical and Materials Sciences To Advance Clean Energy Technologies and Low-Carbon Manufacturing	1-2	Basic and fundamental chemical and materials sciences that underpin clean energy technologies and low-carbon manufacturing
	BER	FY2021: Systems Biology of Bioenergy-Relevant Microbes to Enable Production of Next-Generation Biofuels and Bioproducts	1-2	Subtopic: Biological plastic upcycling organism design
	BER	FY 2022 Biosystems Design for Biofuels, Bioproducts, and Biomaterials	1-2	Genome-wide design and editing, and in vivo or cell-free engineering technologies for eukaryotic or prokaryotic microbes to produce biofuels, bioproducts, or biomaterials from lignocellulosic biomass, petroleum-derived synthetic polymers, or as a byproduct of photosynthesis
	FECM	FY2020: Enabling Gasification of Blended Coal, Biomass and Plastic Wastes to Produce Hydrogen with Potential for Net Negative Carbon Dioxide Emissions	2-3	Co-gasification of coal, biomass, and plastic wastes for production of hydrogen and fuels with negative carbon potential
	FECM	FY22: Carbon Management	3-5	Carbon conversion, carbon dioxide removal, point source carbon capture, and carbon storage
	EERE	FY2020: Bio-Optimized Technologies to Keep Thermoplastics out of Landfills and the Environment (BOTTLE) FOA	2-4	Polymer redesign for recyclability and biodegradability; chemical, biological, thermal, and mechanical deconstruction and upcycling
	ARPA-E	FY2020: Recycle Underutilized Solids to Energy (REUSE)	2-4	Convert unrecyclable plastic and paper into liquid intermediates upgradable into fuels or chemicals
	EERE	FY2020: Bioenergy Technologies Office FY2020 Multi-Topic FOA	2-4	Subtopic: Technologies to transform urban and suburban wastes including plastic into products
	EERE	Funding Opportunity: Single-Use Plastic Recycling (SUPR)	2-5	
Small Business Innovation Research Solicitations (SBIR)	EERE	FY2020: Phase 1 Novel Utilization Strategies for Ocean Plastic Waste	2-4	Utilization of ocean plastic waste
	EERE	FY2021: Phase 1 Compatibilizers of Existing Plastics	2-4	Novel compatibilizer strategies to enable more efficient recycling of mixed plastics
	EERE	FY2019: Phase 1 Release 2—Reshaping Plastic Design and Degradation for the Bioeconomy	2-4	Novel methods for plastic redesign and upcycling
Institute Project Calls	EERE	FY2021: Reducing EMbodied-energy And Decreasing Emissions (REMADE), a Manufacturing USA Institute Project Call	3-7	Enable U.S. manufacturers to increase the recovery, recycling, reuse, and remanufacturing of plastics, metals, electronic waste,

Clean Fuels and Products Earthshot

Using clean carbon sources and conversion technologies:

*This Energy Earthshot assumes that 50% of marine, rail, off-road, hydrocarbon chemicals and 100% of aviation demand will be met by hydrocarbon fuels in 2050.

BOTTLE Consortium – www.bottle.org

Vision

- Deliver **scalable technologies** that enable cost-effective recycling, upcycling, and energy efficiency for plastics

Mission

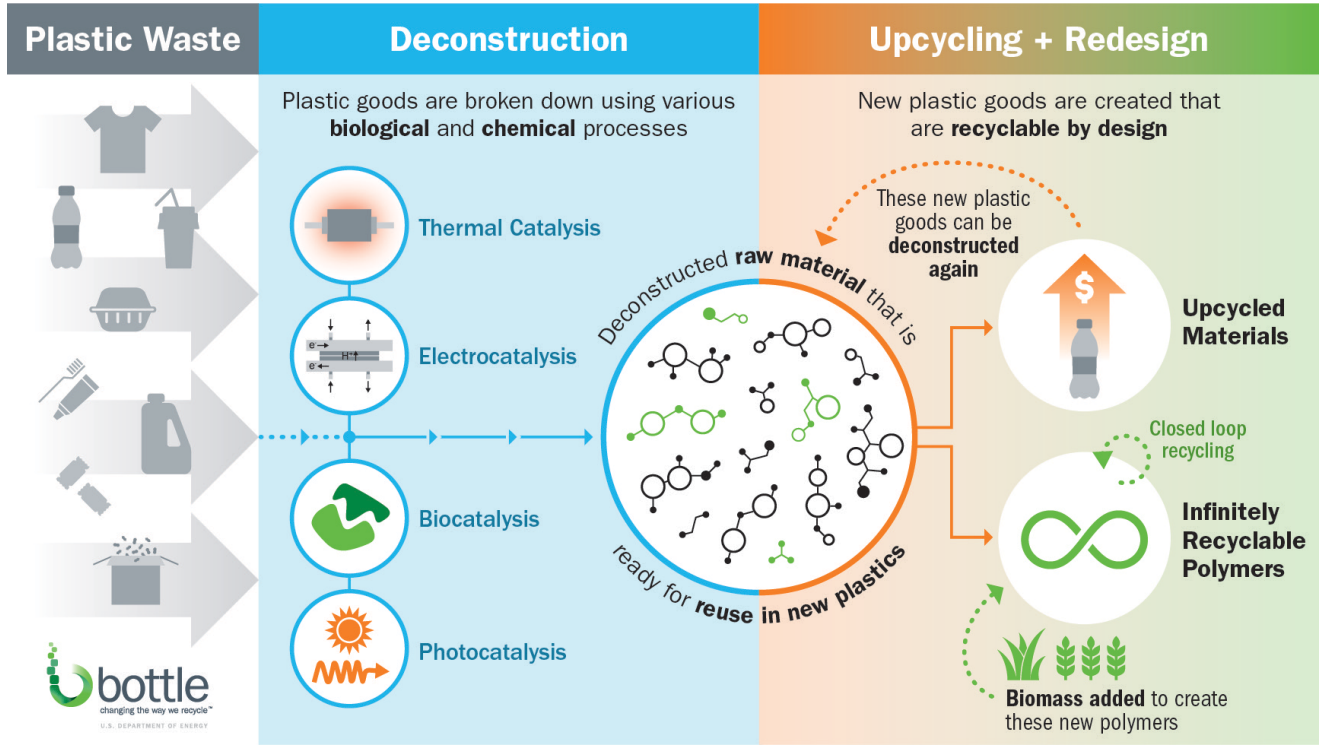
- Develop robust processes to **upcycle** existing waste plastics, and
- Develop new plastics and processes that are **recyclable-by-design**

Goals

- **Work with industry** to catalyze new recycling and redesign paradigms
- Leverage DOE investments in process development, catalysis, materials, and **analysis-driven R&D**

DEI

- A **diverse and inclusive** consortium that fosters the growth of researchers across their career, engages broadly to **educate the public** on our work, and ultimately contributes to the local community and the world broadly



bottle
changing the way we recycle
U.S. DEPARTMENT OF ENERGY

REMADE – www.remadeinstitute.org

REMADE MISSION: Reduce embodied energy and carbon emissions through early-stage applied research & development

- Systems Analysis & Integration
- Design for Re-X
- Manufacturing Materials Optimization
- Remanufacturing & EOL Reuse
- Recycling & Recovery

MATERIAL CLASSES

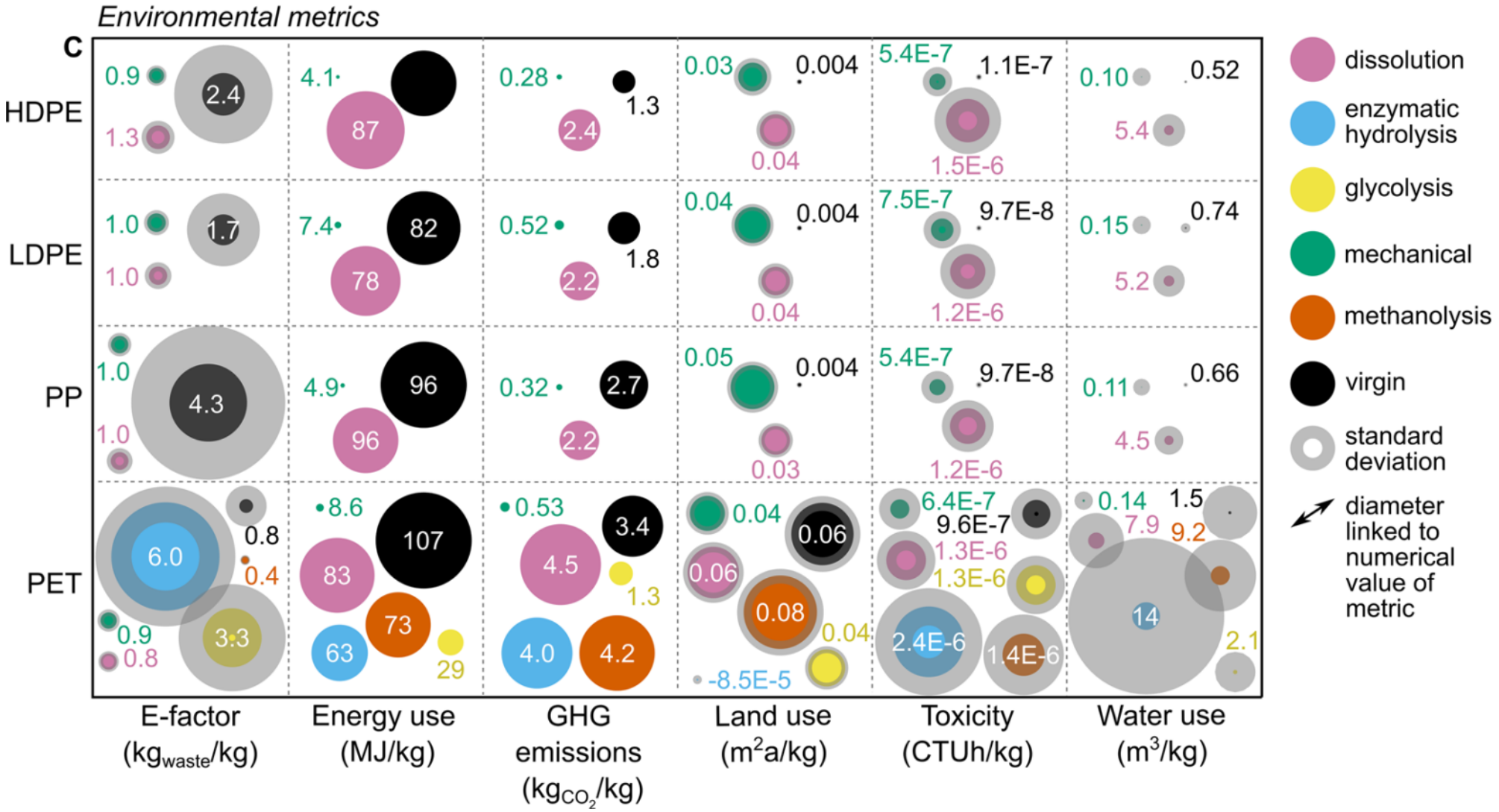
Metals

Polymers/Plastics

E-Waste

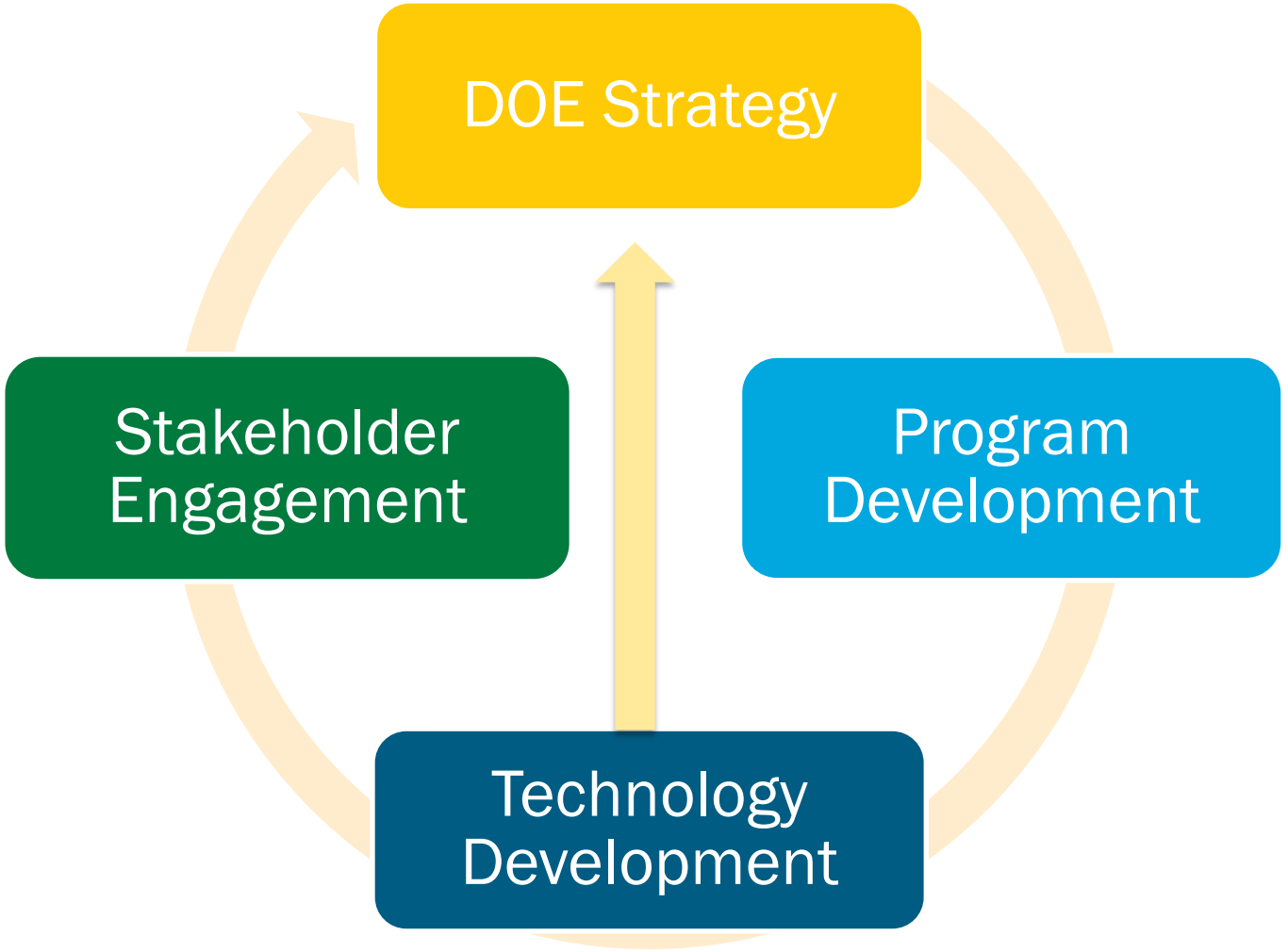
Fibers

Beyond Energy and Emissions



Uekert et al., *ACS Sustainable Chem. Eng.* 2023, 11, 965−978

Cycle of Program Development



DOE Strategy for Plastics Innovation Looking Forward

- Provide technical leadership for a “whole-of-government” approach
- Continue to fund world-class analysis and R&D on the most impactful routes of plastics decarbonization and management
- Collaborate with industry partners to demonstrate novel solutions
- Prioritize solutions that maximize industrial GHG emissions reduction while mitigating environmental effects of plastics on a variety of dimensions
- Reducing plastic-related emissions is a key piece of chemicals decarbonization

Questions?