

# Advancing the Goals of the Clean Fuels and Products Shot through Sustainable Chemistry

April 9, 2024

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Sustainable  
Chemistry  
Catalyst



**Lowell Center**  
for Sustainable  
Production

UNIVERSITY OF MASSACHUSETTS LOWELL

# A bold goal...

“Establish the United States as a world leader in clean fuel and clean carbon-based chemical production, create and maintain new high-quality jobs, and provide enhanced energy security with robust domestic supply chains.”

By 2050, 50% of carbon-based chemicals from sustainable carbon sources.



## Mobilize Renewable Carbon Resources

### Expand and Develop New Feedstocks:

Develop and utilize new technologies to maximize carbon incorporation and retention to generate low-cost, low-emissions biomass, waste, and CO<sub>2</sub> feedstocks at scale

### Examples:

Forest residues, agricultural wastes, municipal solid waste, recycled materials, energy crops, algae, CO<sub>2</sub>



## Carbon-Efficient Conversion

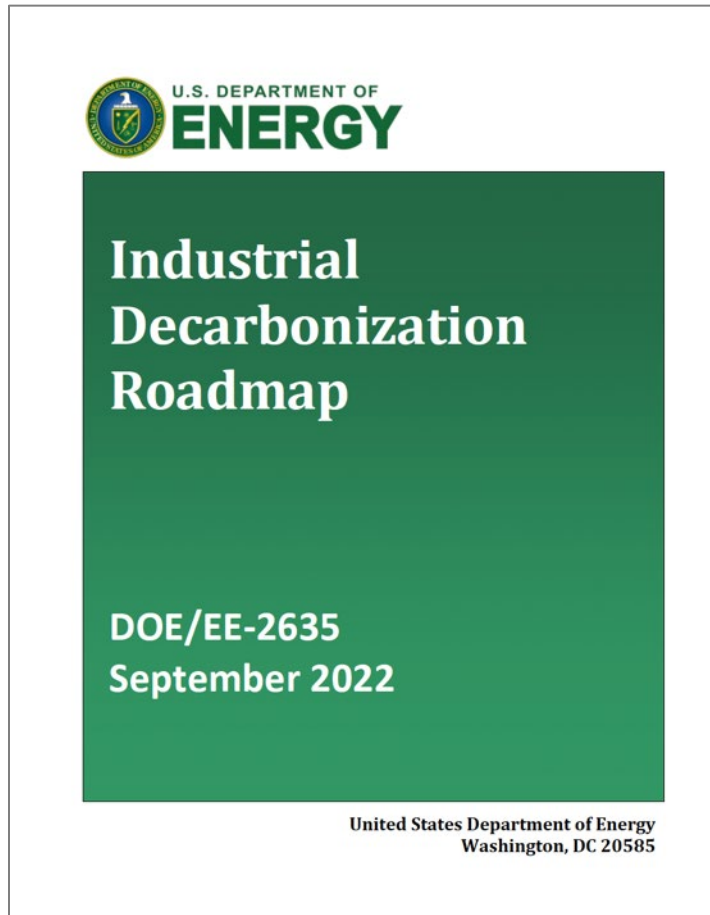
### New Conversion Paradigm:

Develop technologies to maximize conversion of resources into fuels and chemicals utilizing clean power, clean hydrogen, clean heat, and optimized reactor systems

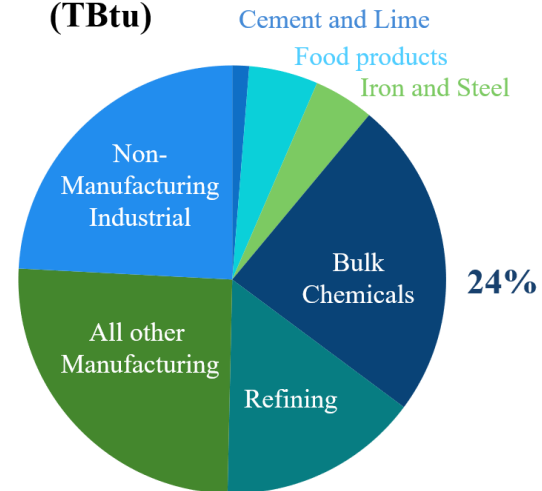
### Examples:

Biomass gasification to SAF, solar fuels, power to liquids, catalytic conversion of CO<sub>2</sub>

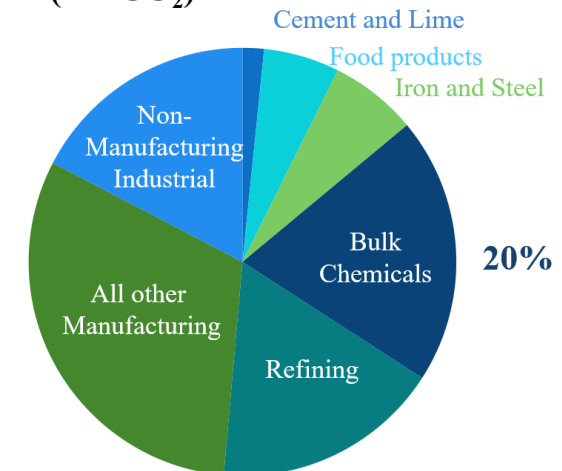
# The chemical industry is the largest industrial carbon emitter...



**Industrial Energy Use (TBtu)**



**Industrial Carbon Emissions (MTCO<sub>2</sub>)**



Non-manufacturing industrial: agriculture, mining, and construction  
Source: DoE Decarbonization Roadmap (Figures 2&3)

<https://www.energy.gov/eere/doe-industrial-decarbonization-roadmap>

# But it is also a large contributor to the plastics crisis and chemical pollution

**ENVIRONMENTAL Science & Technology**

pubs.acs.org/est Policy Analysis

## Outside the Safe Operating Space of the Planetary Boundary for Novel Entities

Linn Persson,<sup>†</sup> Bethanie M. Carney Almoth, Christopher D. Collins, Sarah Cornell, Cynthia A. de Wit,<sup>\*</sup> Miriam L. Diamond, Peter Fantke, Martin Hasselöv, Matthew MacLeod, Morten W. Ryberg, Peter Segard Jørgensen, Patricia Villarrubia-Gómez, Zhanyun Wang and Michael Zwicky Hauschild

Cite This: <https://doi.org/10.1021/acs.est.1c04158> Read Online

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**ABSTRACT:** We submit that the safe operating space of the planetary boundary of novel entities is exceeded since annual production and releases are increasing at a pace that outstrips the global capacity for assessment and monitoring. The novel entities boundary in the planetary boundaries framework refers to entities that are novel in a geological sense and that could have large-scale impacts that threaten the integrity of Earth system processes. We review the scientific literature relevant to quantifying the boundary for novel entities and highlight plastic pollution as a particular aspect of high concern. An impact pathway from production of novel entities to impacts on Earth system processes is presented. We define and apply three criteria for assessment of the suitability of control variables for the boundary: feasibility, relevance, and comprehensiveness. We propose several complementary control variables to capture the complexity of this boundary, while acknowledging major data limitations. We conclude that humanity is currently operating outside the planetary boundary based on the weight-of-evidence for several of these control variables. The increasing rate of production and releases of larger volumes and higher numbers of novel entities with diverse risk potentials exceed societies' ability to conduct safety-related assessments and monitoring. We recommend taking urgent action to reduce the harm associated with exceeding the boundary by reducing the production and releases of novel entities, noting that even so, the persistence of many novel entities and/or their associated effects will continue to pose a threat.

**KEYWORDS:** chemical pollution, plastic pollution, unknown planetary boundary threats, Earth system impacts, cap on emissions, chemical management capacity

**INTRODUCTION**

Chemical pollution has the potential to cause severe ecosystem and human health problems at different scales,<sup>1</sup> but also to alter vital Earth system processes on which human life depends.<sup>2</sup> "Chemical pollution" was included as one of nine planetary boundaries,<sup>3</sup> in response to the understanding. Steffen et al.<sup>3</sup> renamed the "chemical pollution" boundary to "novel entities" (NE), defined as "new substances, new forms of existing substances and modified life forms", including "chemicals and other new types of engineered materials or organisms not previously known to the Earth system as well as naturally occurring elements (for example, heavy metals) mobilized by anthropogenic activities". Steffen et al.<sup>3</sup> argued that the anthropogenic introduction of novel entities to the environment is of concern at the global level when these entities exhibit persistence, mobility across scales with consequent widespread distribution and accumulation in organisms and the environment, and potential negative impacts on vital Earth System processes or subsystems.

So far, no quantitative boundary has been defined for the novel entities boundary, although, some specific chemicals are quantified under other planetary boundaries, such as greenhouse gases and CFCs. Conditions where chemicals may pose a planetary threat have been specified,<sup>4,5</sup> and ways in which cascading systemic effects come to represent a planetary-scale problem have been explored, for example, for plastics<sup>6</sup> (mixtures of nonpolymeric and polymeric chemicals). The high costs to society associated with current use and environmental releases of novel entities<sup>7-11</sup> offer a strong additional arguments for pursuing prompt action addressing

Received: June 23, 2021  
Revised: November 26, 2021  
Accepted: November 30, 2021

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ACS Publications

<https://doi.org/10.1021/acs.est.1c04158>  
Environ. Sci. Technol. XXXX, XXX, XXX-XXX

**UN environment**  
United Nations  
Environment Programme



## GLOBAL CHEMICALS OUTLOOK II

### FROM LEGACIES TO INNOVATIVE SOLUTIONS

SYNTHESIS REPORT (2019)

IMPLEMENTING THE 2030 AGENDA FOR SUSTAINABLE DEVELOPMENT

**UN environment**  
United Nations  
Environment Programme

## A new UN treaty to address plastic pollution

Supporting the transition to a circular economy for plastics



**UN environment programme**

## CHEMICALS IN PLASTICS

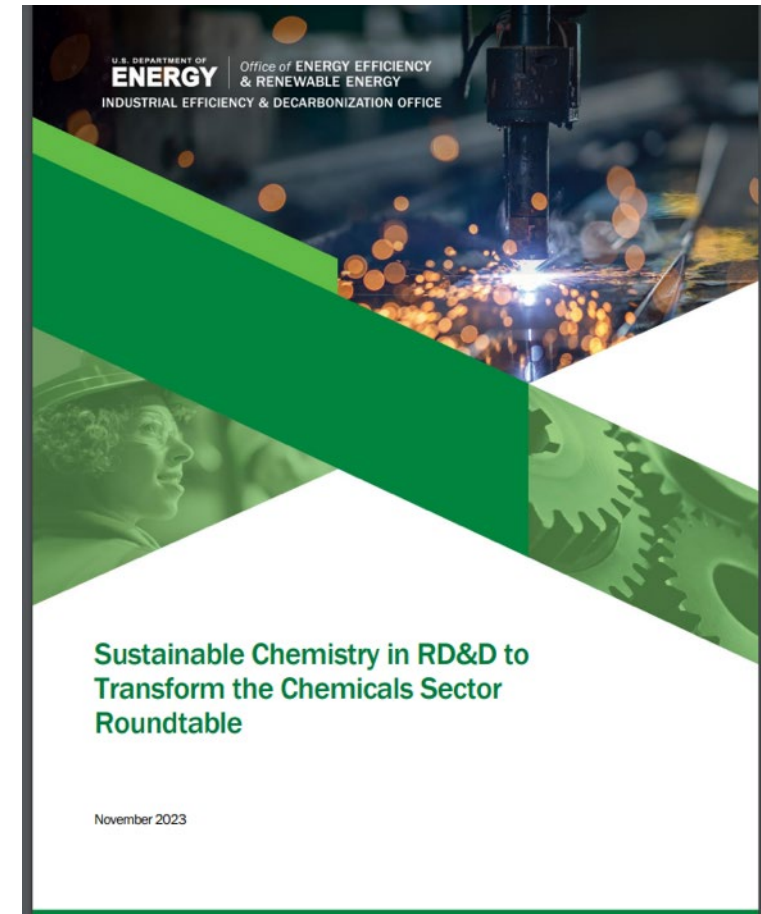
### A TECHNICAL REPORT



UN ENVIRONMENT  
CHEMICALS CONVENTION

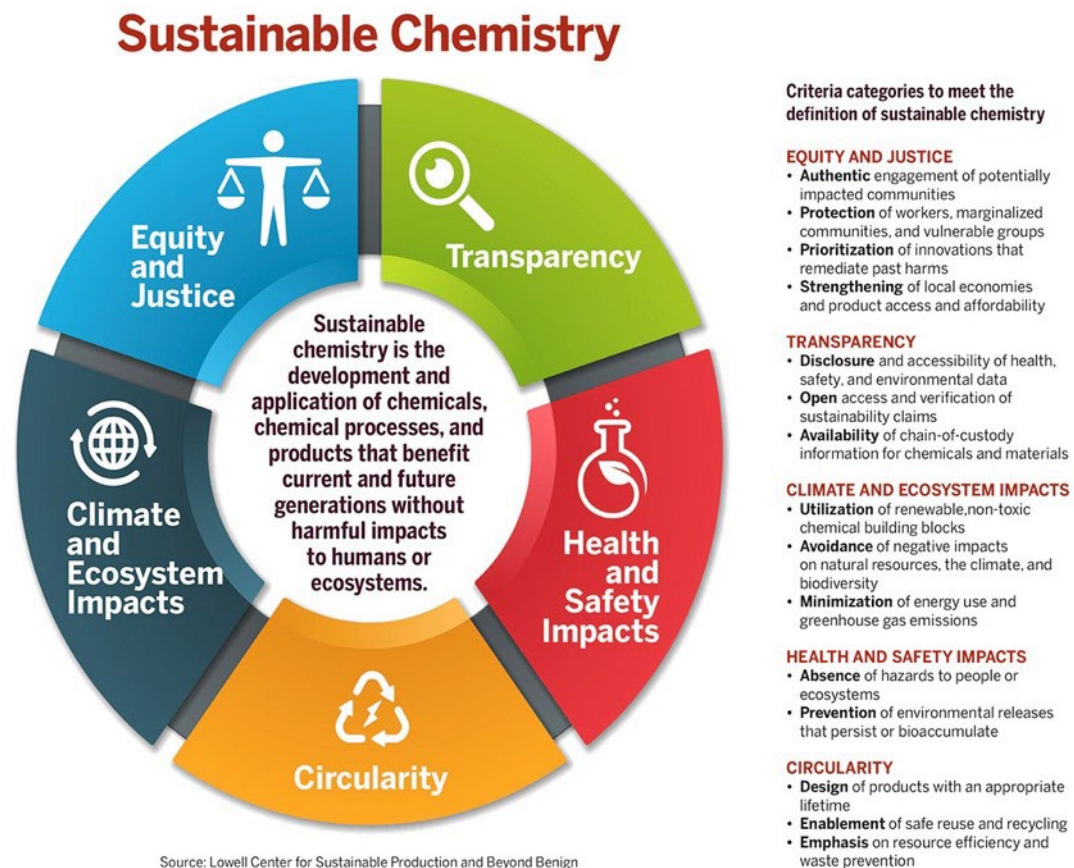
# To avoid regrettable tradeoffs solutions, need to go beyond decarbonization

“The business proposition for investment in sustainable chemistry includes not only decarbonization benefits but also those associated with eliminating chemicals of concern and finding safer alternatives (also referred to as “detoxification”). Such investments may lower cost and financial and reputational risk, increase government compliance, create new market value, avoid regrettable substitutions, and support corporate sustainability targets. Making a strong business case—that sustainable chemistry investments solve multiple challenges and have improved life cycle costs—is critical for market success. “





# Need to be clear on the direction - Sustainable Chemistry



<https://www.sustainablechemistrycatalyst.org/s/Defining-Sustainable-Chemistry-Report-Feb-2023.pdf>

To achieve Earth Shot and Sustainable Chemistry goals will need to advance RD&D at multiple levels....

## Five Conversion Strategies to Transition the Chemical Industry Towards Sustainability



### Energy Conversion

The industry should minimize its process energy requirements and transition from fossil fuels to renewables.

### Feedstock Substitution

The industry should sharply reduce fossil fuel use for feedstocks in the production of chemicals, while building supplies of alternative sustainable, renewable feedstocks.



### Molecular Redesign

The industry should develop innovative, new platform and tunable chemistries based on the principles of green chemistry and engineering.

**Production Process Redesign**  
Chemical manufacturing processes should be redesigned to use renewable feedstocks, minimize adverse impacts, and work within more flexible, distributed, and resilient manufacturing operations.

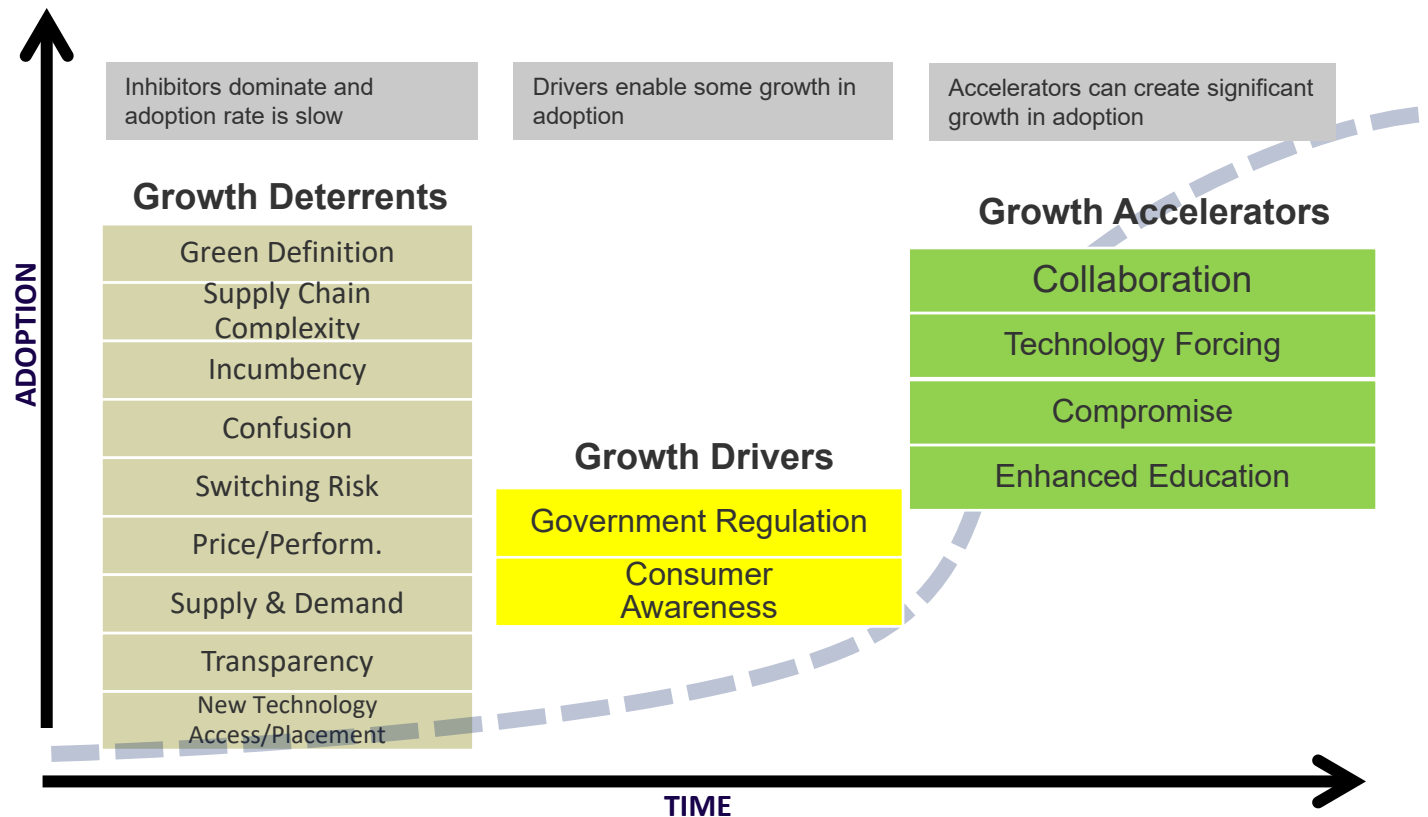


### Downstream Product Redesign

Product design and delivery should be reimagined so that products are more circular, use safer chemistries, and have lower adverse impacts through their lifecycle.

<https://www.tandfonline.com/doi/full/10.1080/00139157.2022.2021793?scroll=top&needAccess=true>

# Barriers and enablers of sustainable chemistry

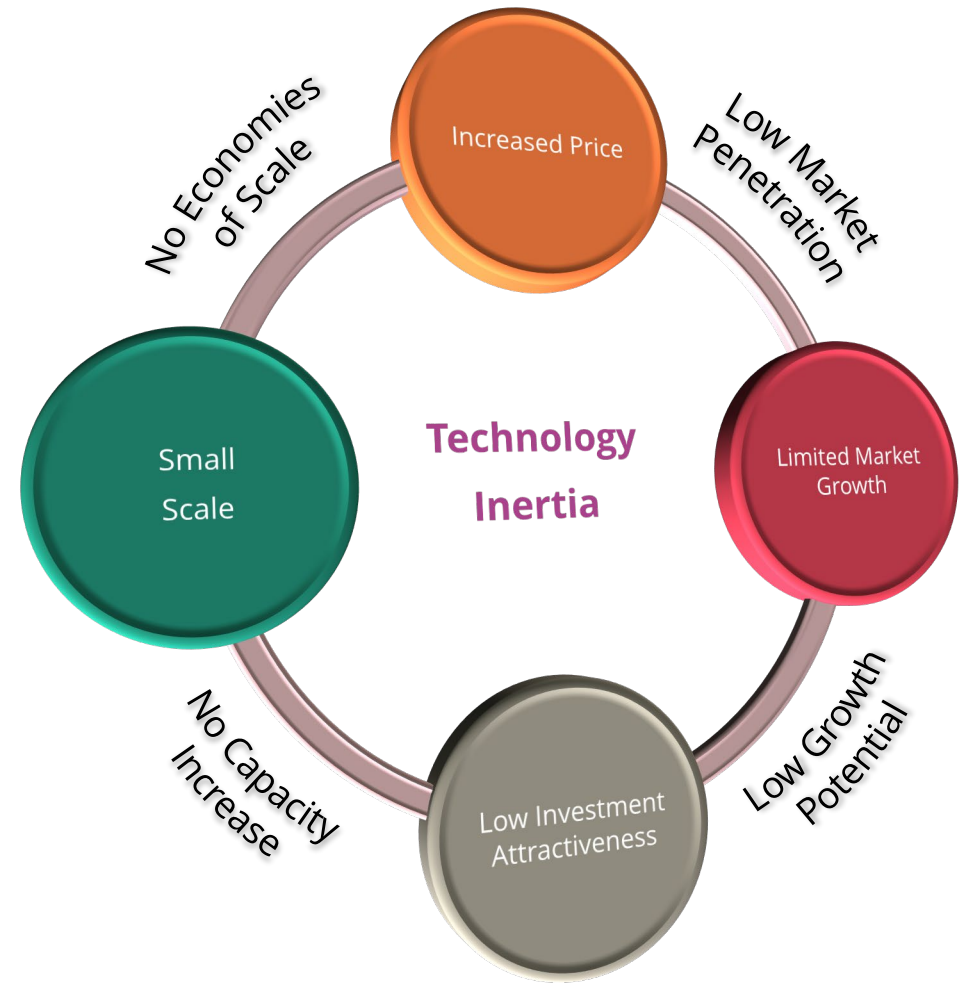


<https://greenchemistryandcommerce.org/resources/gc3-publications>



# Challenges to Sustainable Chemistry Technologies at Scale

- The interplay between scale, price, growth potential and investment attractiveness causes a technology inertia that favors incumbent technologies
- A collaborative approach is needed to:
  - Overcome Technology Inertia
  - Mobilize public and private investment
    - Address risk of new technologies
  - Create policy incentives
    - Demand pull
    - Bridge gap in costs to ensure innovator competitiveness



# Ensuring federal funding from early stage to deployment derisks new innovations from smaller innovators

ENERGY.GOV

SCIENCE & INNOVATION ENERGY ECONOMY SECURITY & SAFETY SAVE ENERGY, SAVE MONEY

Department of Energy

## Biden-Harris Administration Announces \$6 Billion to Transform America's Industrial Sector, Strengthen Domestic Manufacturing, and Slash Planet-Warming Emissions

MARCH 25, 2024

Energy.gov >

Biden-Harris Administration Announces \$6 Billion to Transform America's Industrial Sector, Strengthen Domestic Manufacturing, and Slash Planet-Warming Emissions

*President Biden's Investing in America Agenda Provides the Single Largest Industrial Decarbonization Investment in the Nation's History, Driving \$20+ Billion in Total Investment to Revitalize Manufacturing Communities and Create and Maintain Good-Paying Jobs*

**WASHINGTON, D.C.** — As part of President Biden's [Investing in America agenda](#), the U.S. Department of Energy (DOE) today announced up to \$6 billion for 33 projects across more than 20 states to decarbonize energy-intensive industries, reduce industrial greenhouse gas emissions, support good-paying union jobs, revitalize industrial communities, and strengthen the nation's manufacturing competitiveness. Funded by the President's Bipartisan Infrastructure Law and Inflation Reduction Act, the projects will create and maintain tens of thousands of high-quality jobs and help accelerate the commercial-scale demonstration of emerging industrial decarbonization technologies crucial to meeting the Biden-Harris administration's climate and domestic manufacturing goals.

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY ABOUT EERE RESOURCES BUILDINGS & INDUSTRY RENEWABLE ENERGY SUSTAINABLE TRANSPORTATION

INDUSTRIAL EFFICIENCY & DECARBONIZATION OFFICE

## IEDO FY24 Energy and Emissions Intensive Industries FOA

Industrial Efficiency & Decarbonization Office

Industrial efficiency & Decarbonization Office » IEDO FY24 Energy and Emissions Intensive Industries FOA

Office: Industrial Efficiency and Decarbonization Office  
FOA Number: DE-FOA-0003219  
Available Funding: \$83 million

### Description

On Jan. 25, 2024, the U.S. Department of Energy (DOE) **Industrial Efficiency and Decarbonization Office (IEDO)** announced an \$83 million funding opportunity that will decrease emissions in the hardest to decarbonize industrial subsectors.

Decarbonizing the U.S. industrial sector is key to achieving the nation's clean energy goals. By accelerating the development and adoption of sustainable technologies that increase efficiency and eliminate industrial greenhouse gas (GHG) emissions, this funding will help tackle the climate crisis, boost the competitiveness of domestic manufacturing, and create good-paying jobs for American workers.

**Funding Opportunities**

- Lab Calls

**News & Events**

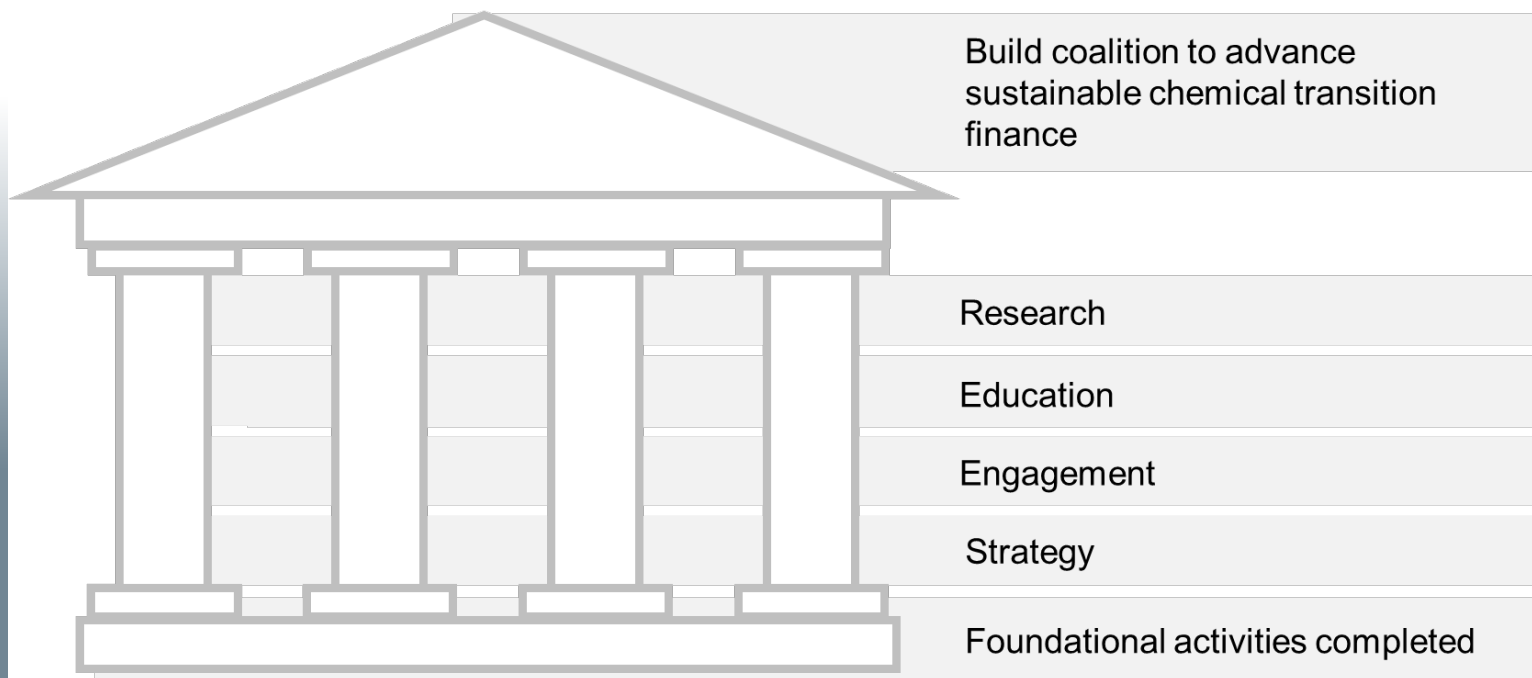
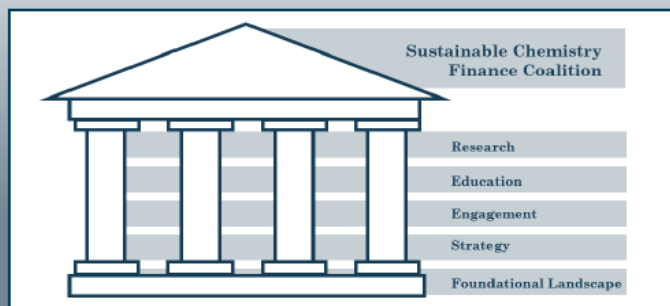
RESEARCH AREAS

**Energy- and Emissions- Intensive Industries Cross-Sector**

# Public-Private Financing Will be Critical to Growing Solutions

JUNE 2023

**Strategic Approach to Transition Finance for Sustainable Chemicals and Materials:  
A Blueprint for the Financial Community**

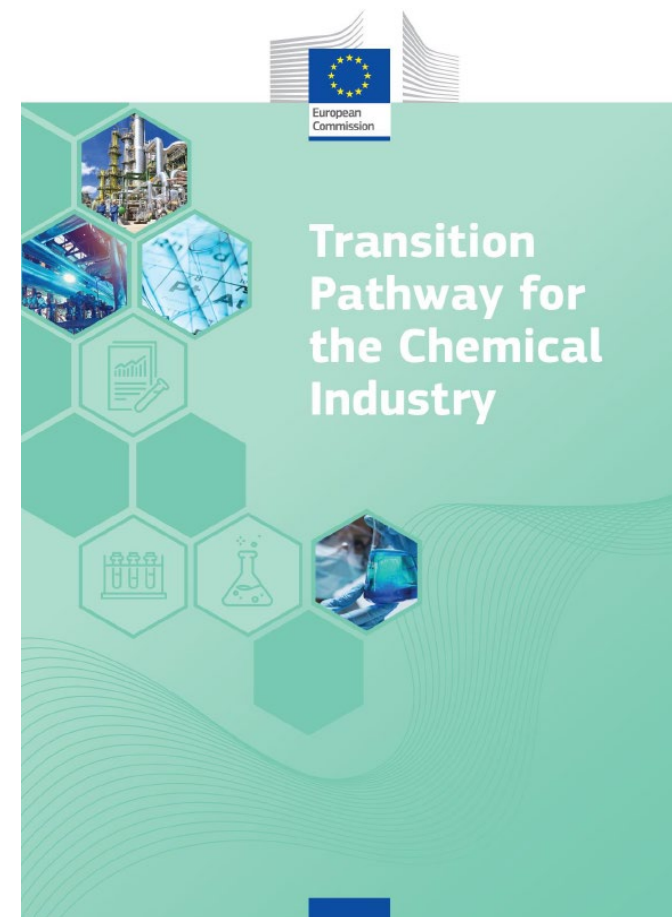
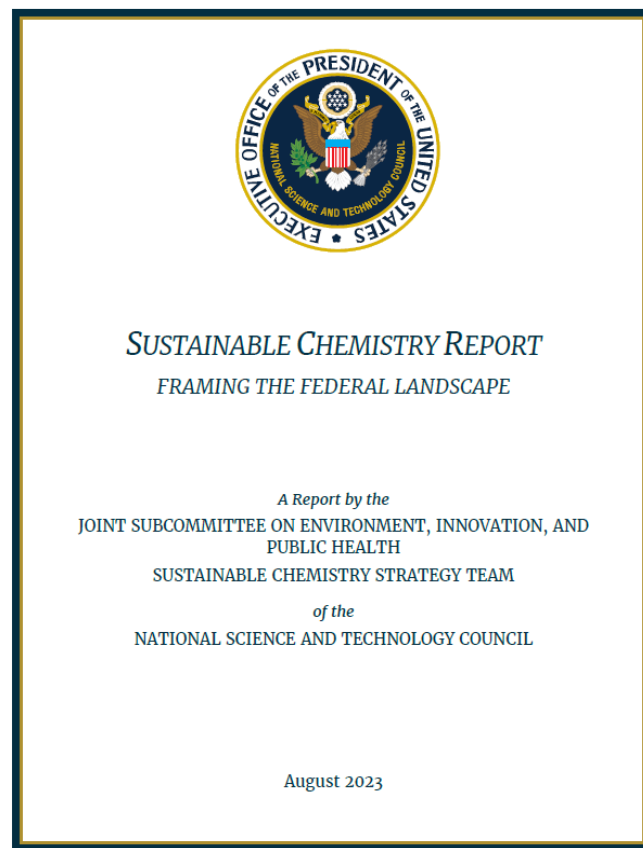
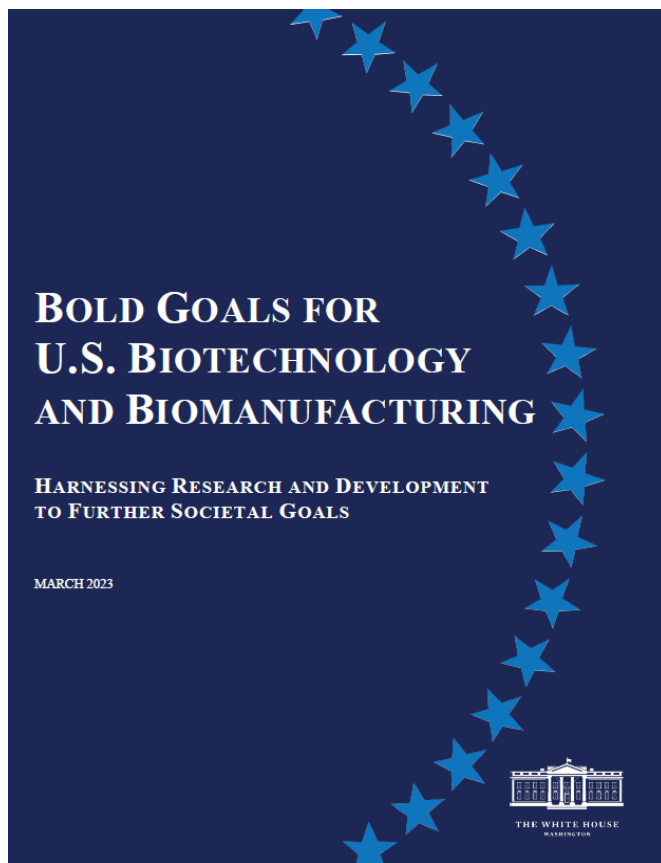


<https://www.sustainablechemistrycatalyst.org/sc-finance>

# And a coordinated federal industrial, financial, and regulatory policy approach

- **Government leadership/commitment to sustainable chemistry** to provide a clear market signal that aligns policy, market actors and other stakeholders
- Clear and time delimited policies that **restrict or disincentivize incumbent chemicals and materials** of concern and the processes that make them
- An **industrial strategy** to focus investment, R&D, and policy towards sustainable chemistry to address key societal and market needs
- Policies that **incentivize investment, deployment and adoption** and create demand
- Incentives for **value chain collaboration** to achieve goals (eg semi-conductors)
- Massive **public and private finance** from early stage through pilots and capital buildout – with sustainable chemistry investment as a clear ESG priority
- Ultimately a **20-30 year roadmap** to change, with interim targets

# A clear roadmap is needed that connects efforts to transform chemistry





Save the date!



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# INNOVATORS ROUNDTABLE

October 28-30, 2024 | Beaverton, Oregon

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[www.changechemistry.org](http://www.changechemistry.org)

Thank you!



Sustainable  
Chemistry  
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*For more information, please visit:*

**Sustainable Chemistry Catalyst** | [sustainablechemistrycatalyst.org](http://sustainablechemistrycatalyst.org)

**A4** | [www.saferalternatives.org](http://www.saferalternatives.org)

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