CASA-Bio
Catalyzing Across Sectors to
Advance the Bioeconomy

Creating Value from Waste Carbon for a Circular Bioeconomy

Waste carbon from agricultural, industrial, and consumer wastes could be transformed into valuable resources like critical materials, fuels, and food. This initiative outlines a bold plan to revolutionize waste management, reduce environmental impacts, and build a more resilient economy.

Marty Matlock, University of Arkansas
Cynthia Ni, Beam Circular
David Zilberman, University of California, Berkely
Adam Leman, Good Food Institute
Marilene Pavan, LanzaTech
Lauren Junker, BASF
Ali Werner, National Renewable Energy Laboratory
Bruno Basso, Michigan State University

October 2024

Creating Value from Waste Carbon for a Circular Bioeconomy

Executive Summary

Waste isn't just a problem – it's a goldmine waiting to be tapped. By 2030, the U.S. will produce enough waste carbon to bury ourselves in 1,500 Washington Monuments every year. This presents an $800 million opportunity to transform our economy and environment.

Imagine a future where our trash doesn't pile up in landfills, but instead fuels our cars, builds our homes, and even feeds our families. This proposal outlines a bold vision for a circular bioeconomy where waste carbon is the key ingredient for a sustainable future. Instead of traditional, linear "take-make-waste" models, a circular bioeconomy reimagines waste as a valuable resource, providing critical feedstocks for strategic materials while minimizing environmental impact and generating economic value.

This transition requires tackling three major types of waste carbon:

- **Lignocellulose**: Found in wood, paper, and agricultural residues, this abundant resource can be transformed into high-performance construction materials, biofuels, and food proteins, reducing our reliance on imports and creating new markets for farmers.
- **C1 Gases (methane, carbon monoxide, and carbon dioxide)**: Captured from industrial emissions and agricultural processes, these potent greenhouse gases can be converted into valuable chemicals, fuels, and food proteins, contributing to a carbon-neutral future.
- **Complex Organic Waste**: Municipal solid waste, food waste, and plastics pose significant environmental challenges. This proposal outlines innovative solutions for biodegradable plastics, advanced recycling technologies, and microbial digestion to generate valuable products and close the carbon loop.

The technologies to utilize these types of waste carbon are within reach. However, achieving this vision requires a coordinated $800 million investment over the next five years to overcome critical challenges:

- **Developing cost-effective technologies** to separate, process, and convert diverse waste streams into valuable products at industrial scales.
- **Building a distributed infrastructure** to support regional waste processing and biomanufacturing, creating local jobs and economic opportunities.
- **Training a skilled workforce** equipped to support this emerging circular bioeconomy, engaging rural and urban communities alike.

The potential benefits are substantial:

- **Environmental**: Reduce pollution, greenhouse gas emissions, and our reliance on landfills.
- **Economic**: Create new domestic industries, jobs, and markets for waste-derived products, reducing our dependence on imports.
- **Societal**: Enhance national security, reduce income inequality, and promote sustainable practices across the supply chain.

Investing in waste carbon utilization is not just good for the environment - it's smart business. By transforming trash into treasure, we can unlock a future where economic growth and environmental sustainability go hand in hand.

Motivation

Carbon is the elemental backbone of life, forming diverse materials such as fuel, protein, plastics, and building materials. Society has historically manufactured goods using raw fossil carbon feedstocks in processes that generate copious amounts of waste. Waste carbon is estimated to reach 1.5 billion dry tons, or the equivalent of 1,500 Washington Monuments, per year by 2030. Efficient utilization of this carbon would transform a waste management problem into an extraordinary economic resource, creating secure, domestic, and circular supply chains and addressing the urgent need to preserve natural resources and mitigate climate change. Creating a circular bioeconomy through waste carbon recovery and reuse requires a foundational investment in targeted research, infrastructure, and technological advancements to achieve this vision at a large scale. We estimate an $800 million investment over the next five years is required to accelerate progress toward waste carbon utilization that will contribute to meeting the urgent climate, economic, and supply chain needs of our nation. Our vision is a circular bioeconomy with virtually no waste, significantly reduced impacts on the environment, and broad economic impacts across the U.S. Our goal is effective waste carbon utilization through biological, mechanical, chemical, and automation innovations.

Creating scalable, economical, and equitable innovations will require coordinated investment and interdisciplinary collaboration. Many individual technological breakthroughs have occurred over the past decade, some of which have been commercialized. However, the holistic integration of these advancements into an effective national system of waste carbon valorization at the industrial scale has yet to be actualized. A coordinated $800M investment will realize this, and in so doing unlock a double-dividend of reducing harmful wastes while producing valuable products. Specifically, critical solutions towards converting lignocellulosic (e.g., biomass and woody materials), waste gases such as C1 (one carbon) molecules (e.g., industrial gases including CO_2, CO, and CH_4), and complex organic waste streams (e.g., municipal solid waste, food waste, plastics, and manure) in scalable and economically feasible ways will be realized. Large-scale utilization of these waste carbon streams will enable a world in which our consumer goods are produced from carbon streams that are already in circulation, thus reducing our extraction of natural resources and pollution of the environment. Achieving waste carbon conversion at industrial scales will also lead to additional benefits, including the creation of new renewable industries that can revitalize rural communities, generate new revenue streams, create jobs, enhance education, and provide energy independence. Furthermore, the diversion of waste carbon from landfills, the environment, and the atmosphere can reduce significant greenhouse gas emissions and water, soil, and air pollution. The described technological solutions could also be adapted for use during spaceflight to address the urgent issue of waste generation in low-earth orbit. Setting precedence for converting waste into new, valuable products would shape the global space economy landscape for explorations in low-earth orbit or on other planetary bodies in the future.

Our proposed actions to enhance waste carbon utilization differ from previous investments and leverage outcomes of past initiatives. Here we propose to focus on research and development (R&D) at lab and pilot scale that enables large-scale separations, processing, and manufacturing using these waste carbon streams leading to the creation of profitable and sustainable industries. These solutions will leverage and be enabled by recent advances in automation, robotics, machine vision, artificial intelligence and machine learning, and biotechnology. Importantly, our focus on translation to widespread commercial scale is distinct from traditional research programs and is necessary to achieve the economic, climate, and environmental impact we seek. Finally, we recognize that implementing waste carbon utilization at scale will require the creation of systems of systems; this will require a long-term effort of crossdisciplinary and cross-sector coordination and collaboration, accumulation of public knowledge, and economies of scale.

We define waste carbon as material produced in the supply chain that has no immediate commercial value, due to the characteristics of the material, or availability and accessibility of markets. Waste carbon streams are as complex and diverse as the processes that generate them, which presents challenges to conversion and the need to dedicate research towards the unique requirements of different types of waste carbon. While this endeavor will be challenging and require significant support in funding, R&D prioritization, and other resources, the potential impact will be enormous.

Research and Development Opportunities, Challenges, and Deliverables

High economic and volumetric waste feedstocks

The bioeconomy has largely been built to utilize refined carbon feedstocks to generate products. However, enormous volumes of carbon are present in many domestic agriculture, manufacturing, and post-consumer wastes that could add to our supply of valuable domestic carbon sources. The DOE's Billion-Ton Report estimates that the US's waste carbon will soon reach 1.5 billion dry tons annually.[1] The carbon building blocks and energy in these materials are a wasted economic and sustainability opportunity for the US. Current uses of waste carbon do not maximize its value and have other pitfalls; energy generation applications further contribute to pollution and recycling is economically unfeasible. Conversion technologies need to be improved or invented to isolate and process diverse carbon feedstocks at scale into valuable products that meet the needs of US consumers.

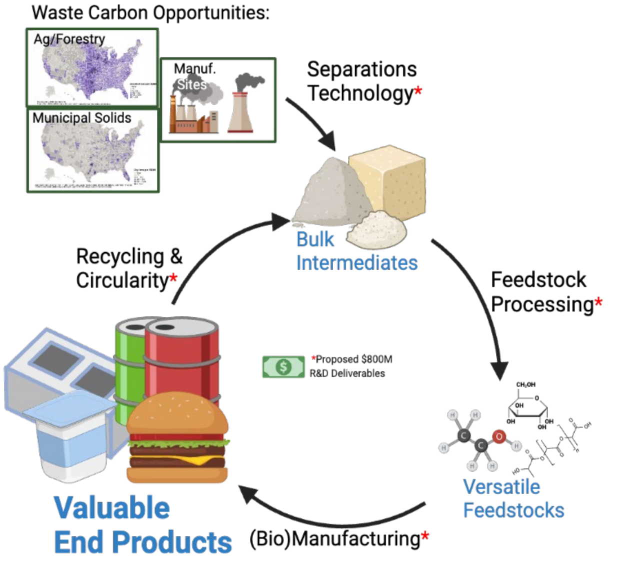

Figure 1. Opportunities for circularity in the bioeconomy through collection, separation, processing, bio-manufacturing, and recovery of carbon-based products. Maps sourced from 2024 Billion-Ton Report.[1]

Carbon waste streams, such as paper, cardboard, plastics, lignocellulosic agriculture and forestry residues, municipal solid wastes, and carbon off-gas from industrial facilities, are abundant and well-distributed between rural, suburban, and urban areas. Removing solid carbon waste streams would reduce waste carbon by >680 million tons. Capture of industrially produced carbon dioxide off-gas waste from manufacturing sites alone could reduce 600 million metric tons of carbon dioxide, 13% of the total US production.[2] These numbers represent significant reductions in US carbon pollution and an opportunity to transform these carbon wastes into building blocks for valuable end products.
Taking a coordinated approach to a diverse set of carbon wastes ensures a geographically distributed and seasonally consistent supply of carbon for manufacturing. New approaches to waste separation and processing are needed to realize the intrinsic value of these carbon sources. Coordinated development

and scaling of these technologies can address several challenges and expand the bioeconomy. For example, these feedstocks could generate food protein through fermentation, helping to secure a domestic production industry to offset a portion of the >$26 billion of imported meat and vegetable oils.[3] Similarly, the generation of organic chemicals from waste carbon feedstocks could help solve the ~$10 billion trade deficit in this sector.[4] Using abundant domestic waste feedstocks to create these high-value end products will meet current needs, address waste management issues, and position the US for continued circularity and economic opportunity (Figure 1).

Three high-level deliverables are presented below, along with recommended R&D milestones to overcome key technological barriers within a five-year timeframe.

Deliverable 1: High-value products generated from lignocellulose at industrially relevant scales

Production of fuels and other high-value products is needed for sustained industrial success of lignocellulosic biorefineries. Lignocellulose is mainly composed of carbohydrates (hemicellulose and cellulose) and rigid cell wall material (lignin). Prior lignocellulosic biorefineries focused on cellulosic fuels, such as ethanol. They failed due in part to low overall conversion efficiency, compounded by feedstock storage and handling issues, high capital costs, and a relatively inexpensive ethanol product. More specifically, these processes did not generate valuable products from the abundant yet difficult to breakdown lignin fraction, but rather burned it for heat generation in a polluting and high-capital cost process. The past decade has been marked by tremendous progress developing technologies to capture the full value of lignocellulose, including fractionation into carbohydrates and lignin, conversion of each fraction into bioproducts, and separation of these bioproducts into pure streams. Lignin-derived bioproducts include high-performance construction materials, petroleum-derived chemical replacements, aviation and marine fuels, and novel chemicals with improved functionalities. In nearly all instances, these have more value than ethanol, and technologies have recently been established to efficiently convert ethanol to higher-value fuels, food, and feed as well.

Major challenges

- **Feedstock processing:** Transportation, handling, and capital costs are high for processing diverse and geographically distributed feedstocks in a centralized model. Processing lignin specifically is challenging as it is notoriously difficult to break down without losing value.
- **Choosing the right product:** While it's well-established that producing ethanol alone is not enough for a fully realized biorefinery, lack of existing markets and clear value chains for new bioproducts makes decision-making challenging, especially in early-stage R&D.
- **Expensive separations:** Product separations are currently costly and resource intensive, and thus have historically been considered as not economically viable for most products in bioprocess development.
- **Process integration:** Bioconversions developed in isolation have often failed when integrated with up- or down-stream processing or with industrially relevant feedstocks.
- **Workforce development:** There is a lack of trained workforce and researchers to meet the projected demand for lignocellulosic biorefineries. Insufficient engagement with local communities and regulatory agencies lead to further challenges in the commercialization landscape.

Major Milestones

- **Local or on-site feedstock processing:** On-site processing approaches should be established and would reduce the overall transport cost by reducing mass and increasing portability, thereby ensuring the creation of local bioeconomies. Smaller-scale processes will also be less capital cost intensive, lowering the barrier for commercial entry. An accessible database mapping waste feedstock availability and seasonality at the city or county level should be leveraged to inform the placement of these facilities.

- **Open-access market, economic, and sustainability analyses:** Establishing open-access tools to measure the market potential and system-level supply chain elements for products on varying timelines would help guide R&D. Transparent, accessible, and self-consistent economic and sustainability (e.g., technoeconomic and lifecycle) analyses should be established and used early and often to prioritize areas for R&D. Such an approach would be differentiating from major efforts which have come before. These analyses could form a roadmap for diverse stakeholders to select target products with the highest technical feasibility, economic viability, and highest sustainability potential.
- **Widespread, easy access to relevant feedstocks, process integration, and scale-up:** Establishing small-scale “plug-and-play” facilities, akin to a user facility, which enable researchers to connect their technology to relevant up- and down-stream unit operations would enable the identification of problem points. Evaluating this critical aspect early in development would be another differentiator from prior major efforts in this space. Existing bioprocess pilot plant facilities or shuttered pulp and paper mills could be revitalized and outfitted with essential downstream processing infrastructure.

Deliverable 2: Storable materials generated from C1 gases at industrially relevant scales

The transformation of low-energy single carbon (C1) molecules, such as methane, carbon monoxide, and carbon dioxide, into higher-value storable products, such fuel, chemicals, materials, and proteins, represents a critical innovation in our quest for a sustainable bioeconomy. Previous efforts to capture C1 gases were focused on separating them from other carbon streams (and venting them) or using C1s in enhanced oil recovery technologies, overlooking their potential in the sustainable bioeconomy. Placing a sustainability focus on C1 will not only contribute to carbon capture, utilization, and sequestration, but also drive the development of a proven, viable circular bioeconomy, creating new economic opportunities and advancing sustainability goals in climate change and environmental quality.

<u>Major challenges</u>

- **Infrastructure challenges:** C1 gases are generated at manufacturing, electrical generation, and anaerobic digestion facilities, which are spread throughout the US. A significant barrier to scaling these technologies is the lack of infrastructure for distributed biomanufacturing across the country. The absence of facilities that can operate at various scales hinders widespread adoption and the ability to address regional differences in feedstock availability and process needs.
- **Technical hurdles in scaling:** Transitioning from small-scale laboratory processes to large-scale industrial applications poses technical challenges. Differences in process dynamics between scales, feedstock quality, and gas mass transfer efficiencies create knowledge gaps that complicate scale-up efforts.
- **Lack of genetic tools:** Another critical barrier is the lack of advanced genetic tools for modifying non-model organisms. Non-model organisms are species that are not traditionally used in research due to limited genetic tools or resources, but they may offer unique capabilities for biological processes or biodiversity. This limits the ability to engineer microbial strains that can efficiently convert diverse C1 feedstocks into desired products.
- **Economic viability:** High capital and operational costs, especially related to energy consumption and feedstock processing, pose economic challenges. These costs, coupled with fluctuating market

demand and regulatory uncertainty, make it challenging to achieve techno-economic competitiveness.

<u>Major Milestones</u>

- **Decentralized infrastructure facility model:** Creating decentralized facilities nationwide that cater to different feedstocks, scales, and process designs would facilitate regional adaptation and ensure a robust and flexible infrastructure for C1 transformation processes.
- **Microbiome and strain development:** R&D efforts should be focused on microbiome co-culturing and strain development to improve feedstock conversion efficiency and adaptability. This includes developing tools for non-model organisms and enhancing the genetic stability of engineered strains.
- **Intermediate feedstock conversion:** Promoting the development and demonstration of technologies that convert gas-phase C1 feedstocks into liquid-phase intermediates would improve the efficiency of bioconversion processes and create more storable materials, thus enhancing the overall value chain.
- **Energy efficiency enhancements:** Improving gas transfer rate efficiencies would reduce energy consumption and operational costs. Advancements in this area are essential to making C1 conversion processes economically viable and competitive with traditional fossil-based methods.

Deliverable 3: High-value products generated from complex organic wastes at industrially relevant scales

The conversion of complex waste carbon streams into higher quality products enhances the circularity of the global carbon budget. However, the heterogeneity of these streams presents challenges for efficient conversion into valuable products. This section discusses high volume wastes with significant environmental impact, including mixed municipal, food, plastic and textile, and animal and manure wastes. Microbial digestion advancements offer a means to generate syngas and other intermediate feedstocks from these food, animal, and agricultural wastes. Currently, plastic recycling is largely economically unviable, resulting in environmental accumulation. Developing biodegradable plastics or improving the recycling of synthetic materials can help address this issue. New (bio)technologies can convert these wastes into high-value products, offering environmental and economic benefits over current practices.

<u>Major challenges</u>

- **Feedstock processing:** Feedstock heterogeneity, variable composition, and regulatory uncertainties of complex waste feedstocks create several challenges. Separation of dispersed waste streams through collection, sorting, solids size reduction (grinding), extraction, and bioprocessing is not cost-effective with current technologies and infrastructure. Furthermore, conversion technologies for mixed inputs are inadequate, and data on feedstock availability and composition is lacking.
- **Infrastructure challenges:** The target final product often varies with the input, and processes lack automation, resulting in high labor intensity. Existing plastics recycling requires labor-intensive waste sorting and creates material with finite re-use cycles or decreased value (‘down-cycling’), leading to unprofitable processes and plastic accumulation in landfills and the environment. Current practices do not take advantage of available basic knowledge and capabilities in an integrated and multidisciplinary way. To address these barriers over the next five years, there is an urgent need for biology, chemistry, and engineering to come together on an industrial scale to develop the infrastructure to generate value-added products.
- **Economic viability:** Industries designed for homogeneous inputs struggle with the cost of collecting and transporting diverse feedstocks. There is a lack of economically and environmentally feasible

technologies at local scales that are also meeting an appropriate economic scale due to a low profit margin, the costly need for purification of end products and lack of reliability. The hand-off from lab-scale experiments to an industry-scale implemented technology is a technical and economic barrier.

- **Regulatory environment:** Waste classification frameworks are underdeveloped, posing challenges for safety, particularly regarding food safety and contamination, and face negative public perception towards byproduct reuse. To ensure the circularity of complex organic waste utilization, regulations must establish science-based, scalable, and public perception-sensitive safety and quality standards. Furthermore, the cost of utilizing waste feedstocks for valuable product production is often compared to conventional petrochemical approaches. Implementing short-term incentives and equitable incentives for biobased and complex waste feedstocks is necessary to make the economics more attractive for investment.

Major Milestones

- **Scalable, automated feedstock separation technologies:** To address the challenges of waste management, it is essential to focus on developing decentralized, efficient, and economic feedstock processing facilities. This can be achieved by improving waste sorting through the integration of artificial intelligence (AI) and automation, which will not only reduce costs but also enhance the quality of the feedstock. Additionally, it is crucial to ensure that the separated products meet the necessary specifications for their intended downstream use. To achieve these goals, fostering collaboration across the fields of biology, chemistry, and engineering is vital. By working together, experts from these disciplines can develop scalable and economically viable processes for waste utilization.
- **Scalable materials reuse and deconstruction processes:** Designing plastics for circularity, reuse, and deconstruction, specifically for single-use products, could achieve carbon loop-closure without downcycling and prevent microplastic generation. Developing low-energy recycling technologies that can handle mixed plastic and textile wastes could reduce feedstock handling costs. Developing bio-based processes for generating the plastic polymer and additives, such as plasticizers, pigments, and stabilizers while maintaining performance requirements, could significantly reduce plastic waste and promote sustainable plastic waste management.
- **Marketable high-value products:** Developing the next generation of arrested methanogenesis, bioelectrochemical systems, hydrothermal liquefaction, gasification, or other technologies to achieve high conversion rates could access valuable products beyond methane. These innovative approaches could unlock the potential of feedstocks that contain valuable byproducts, such as nutrients or metals. Developing efficient recovery into marketable products could improve the process economics, generate new markets and ensure supply chain resilience. To guide product selection, open-access, systems-level analysis tools should be developed and utilized. Additionally, cost-effective and efficient chemical separation technologies for the extraction of products and byproducts should be established.

Cross-Cutting Opportunities

A resilient circular carbon bioeconomy must include system-wide analysis, distributed yet interconnected infrastructure and extensive workforce development, in addition to strong investments in foundational discovery. These elements create the innovation ecosystem necessary to react, respond, anticipate, and innovate for dynamic supply chains.

A life cycle approach to waste carbon creates innovation for sustainability and efficiency at every step of the supply chain, from cradle to cradle. These include waste avoidance, sorting, collection, processing, and transformation. The life cycle approach also frames success in terms of social and economic equity to ensure these new supply chains do not shift burdens inequitably across communities. Waste carbon feedstocks represent a form of common pool resources, so a broad coalition of stakeholders must be engaged in development, implementation, and oversight of these new supply chains.

The distributed nature of waste carbon feedstocks demands distributed and redundant systems for recovering and transforming waste carbon to value. Distributed, interconnected infrastructure will require innovative approaches to modularity and scale of waste carbon feedstock handling and processing, market-driven transformation, and supply chain optimization. Distributed systems can serve as testbeds to adapt to local challenges, opportunities, and resources, such as responding to local demands for carbon products. The smaller scale of distributed facilities reduces timescales, costs, and risks associated with upscaling technologies. The network of waste carbon recovery and transformation systems can be interconnected through dynamic data and technology sharing programs that protect intellectual property while advancing accelerated innovation in a collaborative platform. These distributed systems represent employment opportunities for rural and urban communities alike.

Fostering an equipped and engaged workforce will be essential for transportation, sorting, processing, manufacturing, and distribution of value-added products. Programs to up-skill the existing workforce should be widely accessible and culturally relevant, such as online, subsidized, or bilingual opportunities. Helping students visualize a bioeconomy career would engage the next generation of workforce opportunities. This could be done through common core standards, after school clubs, and partnerships with undergraduate and two-year institutions.

Expected Outcomes and Conclusion

A bioeconomy that utilizes significant waste carbon can yield many benefits; the most direct include reducing the multiple negative environmental impacts of today's waste while creating new materials with economic value. Degradation of carbon-containing waste leads to greenhouse gas emissions and pollution to the atmosphere, environment, and groundwater. Certain waste streams pose further risks, such as increased risk of wildfires from forestry wastes.

Through the described research milestones and deliverables, waste carbon can produce a myriad of valuable products, including chemicals, food proteins and oils, nutrients, sustainable aviation fuels, and high-performance building materials at industrial scales. Proteins are in short supply, and enhancing their production from waste carbon would help reduce environmental impacts associated with concentrated livestock operations. Waste carbon derived products can replace petroleum-derived chemicals, such as ethylene, adipic acid (a nylon precursor), and diesels, reducing fossil fuel demand. Further, bioprocessing can produce chemicals and materials with improved functional properties, such as strategic graphite, infinitely recyclable polymers, carbon-neutral lightweight cement, and higher-performance jet fuel.

Bioprocessing of domestic wastes presents a unique opportunity to concentrate collection, separation, and manufacturing of critical and strategic materials in the US. Metals and minerals that are essential to clean energy technologies, such as graphite, are mostly imported from China.[5,6] Biological processes for the recovery of critical materials from mining, manufacturing, and electronic wastes represents an opportunity to create a domestic, secure, sustainable, and circular supply chains while also mitigating waste collection challenges. For example, bioconcentration and separation of rare earth elements, essential for modern technology manufacturing, is a focus of several federally funded research efforts, such as the DARPA EMBER program[7]. Establishing a coordinated effort to collect carbon and non-carbon wastes can enable enrichment and purification efforts to create viable domestic supplies of critical and strategic materials.

There are also many indirect beneficial outcomes to large scale waste carbon utilization. Products generated from waste carbon could improve national security and competitiveness through new and more resilient domestic supply chains, reducing our dependence on foreign imports. The resulting new industries can provide distributed employment opportunities, especially in rural communities. The value-added products from agriculture and forestry wastes will generate new income sources for farmers and high-quality career opportunities for the rural sector. These opportunities could reduce income inequality across the country, as goods production and knowledge-based employment shift to rural communities.

In addition to developing physical technologies and infrastructure to utilize waste carbon and advance biomanufacturing, our proposed efforts will develop a soft infrastructure to provide a foundation for future innovation and accelerate the scale-up of basic scientific discoveries in the bioeconomy. This new body of knowledge will derisk development and industry scaling while informing regulator bodies of new technologies and approaches. This R&D work will deliver new digital capacity to identify the linkages between waste carbon and the products they can produce, which will provide the scientists and technology developers with better knowledge infrastructure to work with.

The technology and infrastructure described here could be translated into much needed solutions for waste management in low-earth orbit. Commercial enterprises in the space economy are largely unregulated and lack direction on how to properly manage waste, leading to acute problems in the near-term. Developing and deploying (bio)technologies for conversion of waste carbon generated in spaceflight into valuable products would set precedence for not only US endeavors, but across the globe and into future explorations that take place in low-earth orbit or other planetary bodies.
We envision all these broad benefits will result from the R&D deliverables and milestones described herein. These could be achieved in 5 years with an $800M investment to realize early markets for waste carbon-derived high-value products and accelerate longer-term bioeconomy goals.

Authorship and Acknowledgements

This report was written by:
Marty Matlock, University of Arkansas; Cynthia Ni, Beam Circular; David Zilberman, University of California Berkely; Adam Leman, Good Food Institute; Marilene Pavan, LanzaTech; Lauren Junker, BASF, Ali Werner, National Renewable Energy Laboratory; Bruno Basso, Michigan State University.

This report was produced as a part of a multi-organization series of activities, called Catalyzing Across Sectors to Advance the Bioeconomy (CASA-Bio; www.casa-bio.net). CASA-Bio was inspired by the Bioeconomy Executive Order[8] issued by the Biden White House in September 2022, which called in part for collaboration across government, industry, non-profits, and academia to identify key areas for foundational research and development needed to advance U.S. biotechnology and biomanufacturing in five areas: climate change solutions, food and agriculture innovation, supply chain resilience, human health, and cross-cutting innovations. The ideas contained in this report were informed by discussions at a CASA-Bio workshop, “Creating Value from Waste Carbon for a Circular Bioeconomy” that was held

August 12-14, 2024. The authors are grateful for the generous and thoughtful input from the many members of the research and development community who participated in the workshop. The authors also thank the team from Knowinnovation for facilitation and colleagues on the workshop planning committee for invaluable feedback during the preparation of this document.

References

All sources were accessed October 7, 2024.

1. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, 2024. Billion Ton Report: An Assessment of U.S. Renewable Carbon Resources.
2. Congressional Budget Office, 2024. Emissions of Greenhouse Gases in the Manufacturing Sector
3. U.S. Department of Agriculture Economic Research Service, 2024. Summary data on annual food imports, values and volume by food category and source country
4. Observatory of Economic Complexity (OEC), 2024. Organics Import/Export for US.
5. U.S. Department of Energy, 2023. DOE Critical Material Assessment Report
6. United States Energy Association, 2023. Critical Material Recovery from E-Waste, Final Report.
7. Defense Advanced Research Projects Agency, 2024. Environmental Microbes as a BioEngineering Resource (EMBER).
8. The White House. (2022) Executive Order on Advancing Biotechnology and Biomanufacturing Innovation for a Sustainable, Safe, and Secure American Bioeconomy.