CASA–Bio
Catalyzing Across Sectors to Advance the Bioeconomy

Building Resilient Biomass Supply Chains for a Sustainable Bioeconomy

The U.S. must transition from a fossil-fuel-based economy to a bioeconomy that uses renewable biomass. This initiative focuses on creating resilient biomass supply chains to support the U.S. bioeconomy while reducing carbon emissions, enhancing sustainability, and generating economic growth.

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Executive Summary

Challenge

To meet its sustainability goals, the U.S. needs to transition from an economy based mainly on fossil fuels to an economy based on renewable biomass. This will require resilience in the nation's biomass supply chains--to seamlessly harvest carbon in the form of biomass from fields and forests to facilities that convert the raw materials into valuable products like food, feed, fuel, chemicals, and medicines. Currently, biomass supply chains in the U.S. are not up to this task; they suffer from insufficient availability of high-quality raw biomass, aging infrastructure, and mismatches in supply and demand, which often results in economic loss.

Opportunity

A sustainable biobased economy can be achieved by boosting the resilience of existing biomass supply chains and creating new ones. This will require recovery and production of two to three times more biomass over current levels, stronger infrastructure, and more robust connections across all the links in the supply chains--from biomass production, to harvesting and transportation, to processing, to marketing. These changes will help the U.S. meet carbon goals, increase food security, and create jobs.

Solution

This initiative proposes a four-pronged approach to address challenges for building resilient and sustainable biomass supply chains to support a vibrant U.S. bioeconomy.

- **Optimized Biomass Supply Chains:** Better supply chains can be designed by using new data-driven tools that taking advantage of artificial intelligence and real-time data, incorporating principles of sustainability, and expanding and re-skilling the workforce.
- **Diversified, Sustainable Biomass Sources:** Incorporating diverse sources of biomass--such as from plant, marine, waste, and microbial sources--and using climate-smart agriculture and sustainable forestry practices will ensure future environmental health and resource availability.
- **Improved Collection and Conversion Steps:** Existing transportation infrastructure and idle or underutilized processing plants could be used to enhance collection and conversion of aggregated biomass (e.g., soy hulls, wood waste, food waste) for use as new valuable sources, thus mitigating seasonal variations in biomass availability, reducing waste, and maximizing resource use.
- **New Commodity Markets:** Creating new standards for classifying and assigning value to raw materials, like agricultural and forestry residues, will be crucial for making biomass economically viable and reducing the risks of investing in these materials as commodities.

Cross-cutting Advancements

Investments in foundational discovery, applied research and development, data standardization and integration, workforce development, and responsible innovation will be crucial for success.

Impact

A resilient biomass supply chain is not only about strengthening individual links but also about ensuring strong connections between them. This requires coordinated and transparent collaboration across all stakeholders. By investing in research and development across all the steps in biomass supply chains, prioritizing renewable sources, and minimizing waste, we can ensure a thriving future for the U.S. bioeconomy.

Motivation and Justification

Biomass, which is defined as renewable organic material derived from plants and animals, is vital for building a sustainable and thriving bioeconomy. Each year, hundreds of millions of tons of biomass from agriculture and forestry are produced and turned into food, energy, materials, and medicines. For the U.S. to transition from a fossil-based economy to one based on biomass, two to three times more biomass will need to be recovered or grown, harvested and converted into a range of products. Simultaneously, the supply chain networks will need to be reinvented.

That said, the U.S. faces significant challenges in developing and maintaining resilient biomass supply chains[1]. Unlocking the full potential of biomass relies on a well-coordinated and robust supply chain, moving raw materials (feedstocks) from farms or forests to final marketable products. Much like a physical chain, this chain is only as strong as its weakest link, and a break in one part creates disruptions in other parts of the chain (Figure 1). Inconsistencies in the availability of raw materials and aging infrastructure–from transportation networks to processing facilities–pose severe risks to the continuity of these systems. The pressure to modernize and innovate within these supply chains to produce cost-effective biobased products at large scale--without sacrificing performance or increasing environmental impact--is mounting as industries increase their use of biomass to achieve the nation's economic and climate goals.

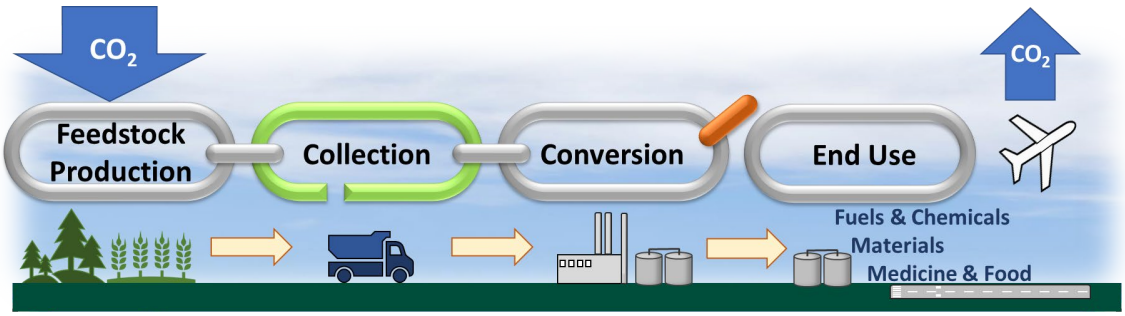

Figure 1: Diagram of a carbon-based biomass supply chain including steps for feedstock production, collection, conversion, and valuable products for end use, such as sustainable aviation fuel, chemicals, materials, medicines, and food. Broken (green) or disconnected (orange) links will disrupt the chain.

Transitioning from a fossil-based to a biomass-based economy in the U.S. is imperative for the nation to meet its targets for global sustainability. According to the Environmental Protection Agency, carbon dioxide (CO_2) emissions account for about 80% of total gross human-caused greenhouse gas (GHG) emissions.[2] Burning fossil fuels for energy accounts for 74% of total GHG emissions and 93% of total human-caused CO_2 emissions in U.S.[3] New supply chains must be developed to support industries such as aviation–where the U.S. aims to produce 3 billion gallons of sustainable aviation fuel per year by 2030[4]–and other sectors that rely on critical materials like protein, natural rubber, or other bio-based raw materials for manufacturing. Moreover, integrating waste carbon sources into the biomass supply chain will enhance its value while reducing fossil fuel demand and supporting national security by reducing reliance on foreign sources for essential materials. Immediate action is necessary to avoid delays in meeting these rapidly approaching targets.

Biomass supply chains are significant economic drivers for agriculture, forestry, and U.S. manufacturing, and important steps can be taken to maximize this benefit. The U.S. can modernize its biomass supply chains by repurposing existing facilities and supply chains, developing new ones, and expanding feedstock availability to enable production of higher-value products. The U.S. is a large country with variable climate, soils, and human capital, such that existing and new biomass resources vary across geographies. Careful consideration of regional integration will be essential to ensure steady and reliable supply chains, especially in rural areas where there is high potential for jobs to be retained, upgraded, or newly created. Moreover, regional integration will allow for efficient use of available feedstocks in the short term, while longer-term solutions, such as developing new biomass crops, are enabled through research and innovation. By connecting biomass supplies among regions, the bioeconomy can maximize value and minimize disruptions, ensuring the supply chain remains robust, cost-effective, and environmentally sustainable.

In short, a resilient and adaptable supply chain system is essential for ensuring the continued growth of the bioeconomy, reducing greenhouse gas emissions, and supporting economic development across the U.S.

Deliverables

This new initiative proposes a $1B investment in four key deliverables that address different components of the biomass supply chain (Figure 1). The first deliverable takes a holistic view of the entire system and provides actionable ideas that can be applied across every link in the chain. The second deliverable focuses on the first link, examining strategies for diversification and sustainability. The third deliverable delves into enhancing the collection and conversion processes, while the final deliverable considers the end-use link, proposing the creation of diverse new commodity markets from biomass.

Deliverable 1: Optimized Biomass Supply Chains

Current supply chains have been developed over decades, often through opportunistic matching of end-use needs with available feedstocks. Many of these existing supply chains provide solid foundations for the bioeconomy. However, most have not been updated and optimized to take advantage of the latest technologies, newly available data, and modern methods for gaining knowledge from data integration. This creates inefficiencies and risks for breaks in the chain along the system, which are exacerbated by the lack of standards or procedures to support supply chain modernization.

To address these gaps and build a resilient future for biomass supply chains, new standardized strategies are needed to help design, develop, implement, and assess supply chains, considering all the steps in the chain, from feedstock production to end-of-life (Figure 1). New tools must be data-driven and designed to leverage information currently used in models, such as Life Cycle Assessment (LCA) and Technoeconomic Analyses (TEA) to assess environmental and economic impacts. Examples of information to use in the new tools include: knowledge about current market drivers, goals for regenerative and sustainable growth of source materials, opportunities for improved harvesting, collecting, and processing, and many other factors that impact the economic value of a supply chain. Incorporating Artificial Intelligence (AI) for enhanced data analysis will also be essential, allowing for deeper insights and optimization at every chain stage. In addition, data standardization across diverse feedstock sources and geographic regions will ensure consistent, high-quality assessments and

transparency. Moreover, transdisciplinary collaboration and transparency should be driving factors for tool development.

Purposeful optimization of new supply chains requires adhering to principles for sustainability (environmental, economic and social) and circularity (reducing and reusing material to minimize wastes), recognizing and removing inefficiencies, facilitating improved use of feedstocks to generate new products, and, where possible, enabling flexibility so that the chains can be scaled, adapted, and adopted for other combinations of feedstock and products. Methods and tools must be developed and designed to handle dynamic, real-time data, improving the supply chains' resilience to shifting market and climate conditions.

It is important to recognize that technological advancements alone will not be sufficient. Expanding a highly skilled workforce is equally critical. Professionals must be equipped to perform work at every step in the chain, from growing and producing the feedstocks to collecting and harvesting to pre- and final processing to marketing.

By integrating modern tools and a skilled workforce, the impact of optimizing supply chains will be substantial. These advancements will create new opportunities for more effective use of raw materials for higher value products, minimize petroleum-based building blocks or materials, promote economic growth, create jobs, and help grow the bioeconomy while reducing the carbon impact of supply chain systems.

Key Actions and Milestones

Produce innovative data-driven tools for designing and assessing supply chains, from feedstock production to end of life	● Incorporate diverse data streams and AI to develop and validate a robust engineering process model of the various supply chains and couple this with integrated LCA/TEA, with the milestone of a producing a validated sustainability toolset. ● Develop and implement standards for testing and data reporting protocols across diverse feedstock sources and geographic regions, with the milestone of producing broadly adaptable LCA/TEA for transparent biomass recovery and supply chain assessment. ● Foster transdisciplinary coordination with relevant stakeholders, including industry, with the milestone of harmonizing methods and standards across agriculture, engineering, economics, and environmental science to ensure successful collaboration and transparency.
Promote circularity and environmental sustainability	● Optimize resource use, minimize waste, and maximize carbon sequestration by determining the forms of biomass that result in energy efficient collection storage and transportation, with the milestone of contributing to climate goals and improving environmental outcomes such as biodiversity conservation, air quality, and water management. ● Promote a circular bioeconomy for bioplastics, chemicals, and critical materials, with the milestone of creating more resilient and sustainable industries that support U.S. economic and environmental goals and utilize U.S. generated biomass feedstocks.

Promote scalability, adoption and adaptability	● Ensure tools and systems are scalable to accommodate growing supply chains and enhanced recovery of existing biomass sources, with the milestone of adapting small-scale, region-specific models for larger, more complex supply chains. ● Ensure that tools accommodate dynamic, real-time data to improve supply chain resilience and adaptability, with the milestone of ensuring long-term viability and stability of the bioeconomy in response to climate and market fluctuations.
Expand and re-skill the workforce	● Develop workforce training programs at existing agriculture and forestry processing facilities focused on increasing skills related to new technologies, with the milestone of enhancing recruitment and retention. ● Develop partnerships between industry and local or regional educational institutions at 2-, 4- and 5+ - year levels to develop curricula for biobased engineering and manufacturing, with the milestone of preparing the future workforce to contribute at all stages of the supply chain pipeline from feedstock production to retail marketing.

Deliverable 2: Diversified, Sustainable Feedstocks

With optimized tools and strategies in place for improving the entire biomass supply chain, the next critical step lies in addressing the foundation of the chain: the feedstock. Ensuring a steady, diverse, and sustainable biomass feedstock supply is key to maintaining resilience throughout the system. This deliverable delves into the first link in the supply chain—feedstock production—exploring how diversification and sustainability efforts can enhance both supply chain reliability and environmental outcomes, driving the bioeconomy forward.

Feedstocks are of paramount importance for the strength and resilience of the chains. Flexibility and diversification in feedstock choices are key factors for enabling efficient use of biomass while simultaneously addressing carbon and sustainability priorities. For example, new supply chains can be 'fed' with by-products from the processing of grains, oilseeds, and wood, thereby enhancing the efficient use of materials that generate less waste and promote circularity. This kind of flexibility not only promotes sustainability but also capitalizes on regional availability of feedstocks from diverse sources—including from plants, marine, waste, and microbial origins coupled to enhanced collection, densification, transport, and storage—while making use of existing processing infrastructure that can be repurposed for new biomass supply chains.

To ensure these diverse feedstocks contribute to long-term sustainability, adopting climate smart agricultural techniques, such as better tillage, cover cropping, and sustainable forestry practices, are critical to ensuring long-term environmental health and resource availability. Incorporating diverse feedstocks into current crop portfolios and plantation rotations may be challenging for farmers and foresters whose familiarity with non-traditional sources may be limited and the value may be unclear. Thus, successful incorporation of new feedstocks and efficient collection of existing ones will require studies to understand the willingness of growers to adopt new practices and to identify specific measures to encourage their participation in a diversified bioeconomy. Addressing public perceptions about production and use of biomass for energy, food, medicines, and materials will also be crucial for fostering support for a diversified bioeconomy.

Ultimately, the potential impact of diversifying the first link in the supply chain is substantial. U.S. agricultural and forest processing industries currently produce large quantities of biomass co-products and wastes that could serve as valuable feedstocks for supply chains, thereby minimizing the carbon footprint, increasing sustainability, and simultaneously generating bioeconomic growth for the U.S. By aligning future market demands with these sustainable practices, supply chains can remain both economically viable and environmentally responsible as the bioeconomy grows.

Key Actions and Milestones

Incentivize climate smart agricultural and sustainable growing practices for a more circular bioeconomy	● **Accelerate the adoption of climate-smart agricultural practices,** with the milestone of reducing the carbon impact of row crop production while maintaining yields and lowering fertilizer and chemical inputs, through better tillage, expanded use of cover crops, and incorporation of automated harvesting and processing technologies. ● **Accelerate the adoption of sustainable forestry practices**, with the milestone of valuing the climate, ecosystem, and social benefits forests provide, supported by improved logging and processing technologies for accessing dispersed forest resources. ● **Incorporate biomass coproducts and wastes from agricultural and forestry processing into feedstock supply chains to promote circularity and resource efficiency**, with the milestone of reducing waste and maximizing the use of existing materials to support a circularity. ● **Understand public perceptions about the use of wood and agricultural biomass for products, energy, and materials**, with the milestone of creating a strategy to align these perspectives to grow the circular bioeconomy through increases use of residues.
Encourage regional development of biomass crops	● **Identify suitable regions for specific biomass crops,** considering proximity to processing facilities, with the milestone of utilizing existing transportation infrastructure and available workforce to support the supply chains. ● L**everage, repurpose, and upgrade existing regional processing infra-structure** from traditional agricultural and forestry supply chains, with the milestone of more efficient use of available resources for the new biobased ecosystem. ● **Implement large-scale test plots and supply chains of new biomass crops to confirm models**, with the milestone of initiating the expansion of biomass supply.
Diversify feedstock sources, where possible	● **Leverage feedstocks from multiple bioeconomy sectors**–including green (crops, grasses, trees), blue (algae and marine organisms), brown (food and animal wastes), and microbial (bacteria and fungi)--with the milestone of making the most of local or regional sources. ● **Tailor feedstocks with relevant supply chains and end products**, with the milestone of selecting feedstocks best suited for optimal production of valuable co-products and end products. ● **Maximize sustainability and circularity**, with the milestone of meeting these overarching principles for environmental and social well-being.

Conduct studies to understand how behavior and economics influence willingness to adopt new crops and practices	● **Utilize private sector marketing, extension programs, and farmer-to-farmer networks to encourage sharing of best practices,** with the milestone of rapidly building farmer confidence in cultivating new crops. ● **Develop an understanding of where and how innovation is needed in a supply chain,** with the milestone of optimizing economic, environmental, and social sustainability. ● **Conduct market analysis and demand forecasting** to assess future needs and ensure that supply chains align with projected market demands, with the milestone of developing strategies to match feedstock production to emerging bio-based product markets.

Deliverable 3: Improved Collection and Conversion Mechanisms

With a diversified and sustainable feedstock base established, the next challenge is ensuring that these materials are efficiently harvested/collected and converted into valuable products. The strength of any biomass supply chain depends not only on the availability of feedstocks but also on how effectively these resources are gathered, stored, processed, and transformed. This deliverable focuses on improving the collection and conversion mechanisms of existing and new sources of lignocellulosic biomass—the second and third links in the supply chain—to enhance efficiency, reduce waste, and maximize the value of these diverse biomass sources. These improvements will be critical in creating a streamlined, scalable system that supports bioeconomic growth and sustainability goals, and engages the rural economy in the sustainable production of biomass feedstocks at scale.

Existing and idle processing plants in agriculture and forestry could be put into service for pre-processing, thereby obviating the need to build new infrastructure to support improvements in these links in the supply chain. Adjusting collection and conversion steps would have the benefit of mitigating seasonal variations in availability of biomass for downstream processing, for example by improving storage capabilities through densification and other techniques. By optimizing collection, conversion, and storage, materials that are traditionally burned, such as wheat straw and forest operations residuals, will be transformed into high-value products, thus increasing the economic viability of biomass supply chains. This would be a huge boon to resilience of supply chains at large.

<u>Key Actions and Milestones</u>

Regional development of densification technologies	● Develop energy-efficient, standardized technologies for densifying (collecting/compressing/stabilizing) and pre-processing biomass, with the milestones of reducing volume to minimize transportation costs, increasing stability to facilitate longer-term storage, and improving feedstock quality for further processing. ● Incorporate data from both economic and environmental models when evaluating new densification technologies, with the milestone of maximizing return on investment and environmental benefit.

Repurpose idle and underutilized assets	● Assess the potential to repurpose closed facilities, with the milestone of identifying opportunities to leverage existing infrastructure and supply chains, workforce, and community relationships to revitalize these assets, while using existing agricultural supply chains as templates applied to new sources of biomass. ● Utilize existing supply chains and conversion infrastructure to repurpose materials traditionally burned or sent to landfills, with the milestone of transforming materials like black liquor, soybean hulls, corn stalks, sugarcane bagasse, or wood waste into high-value products. ● Develop low-cost and robust methods for intelligent deconstruction of woody biomass, agricultural residues, and recycled wood streams, with the milestone of enabling production of multiple types of high-value products from lignocellulosic materials.

Deliverable 4: New Commodities and Markets

With more efficient collection and conversion mechanisms in place, the next step in strengthening the biomass supply chain is exploring market development opportunities. As advancements in densification, pre-processing, and quality increase the availability and value of biomass, the potential to create diverse, high-value products grows. This deliverable focuses on capitalizing on these improvements by developing new commodity markets that can harness the full potential of biomass, driving economic growth while promoting sustainability. Unlocking these markets will be key to expanding the bioeconomy and ensuring that every step of the supply chain contributes to its long-term success.

Designing new supply chains or modifying those that exist must be informed by market pull. Multiple factors should be considered, such as new uses for traditional products, the potential for supply chains to generate valuable co-products, and the possibility of creating high value from low-value or previously discarded products. Also, there is great opportunity to leverage diverse feedstocks to increase biomass availability, thereby providing the raw materials for new, perhaps single-product pipelines.

Biomass in the U.S. is a huge asset, whose immense value is yet to be realized. This is especially true for nascent markets to trade agricultural and forestry residues as commodities. Establishing standardized methods for classifying biomass materials will ensure consistency in valuation, making it easier to trade these materials efficiently across regions. Application of new tools for classifying these materials and technologies would allow for rapid assessment of characteristics, and thus value. Similarly, incorporating new methods for collecting and densifying these materials might contribute to new markets located outside the feedstock production regions.

A commodity market for biomass materials would reduce investment risk by providing a mechanism to manage supply, price, and geographic availability. The development of new commodity supply chains and markets will also support national priorities, such as ensuring the domestic supply of critical food, fuel, medicine, and materials necessary for national security.

Key Actions and Milestones

Create new biomass commodity trading markets	• **Focus on the development of commodity markets that support national goals,** such as ensuring access to critical materials important for national security and other strategic industries, with the milestone of establishing markets for critical biomass-derived materials of high value. • **Create systems for trading biomass residues from agriculture and forestry, making these materials available as tradable commodities on national and international markets**, with the milestone of creating new markets for these residues, contributing to the expansion of the bioeconomy. • **Establish standards and develop technologies to quickly assess and value different biomass materials**, facilitating their trade in emerging markets, with the milestone of streamlining the valuation process to ensure the efficient trading of biomass residues.

Cross-cutting Considerations

Foundational Discovery

Foundational research is critical for spurring innovations across biomass feedstock production, collection, and conversion processes. For example, Deliverable 2 relies on fundamental plant sciences and bioengineering research to develop resilient and diverse feedstocks that meet sustainability goals. Discoveries in drought resistance, pest tolerance, and microbial interactions are key to ensuring feedstocks can adapt to varying environmental conditions and support long-term productivity. Crop and tree improvement can also optimize the diversity of high value products and reduce processing costs. Deliverable 3 benefits from foundational advances in process optimization and biomass conversion technologies, enabling the creation of standardized, energy and carbon efficient methods for handling biomass from feedstock production to final conversion. The focus on densification technologies and repurposing infrastructure relies on fundamental breakthroughs in understanding the deconstruction of lignocellulosic materials and the development of high-value products from previously underutilized biomass. Collectively, these discoveries provide the scientific foundation that enables new tools, standards, and technologies to flourish across the bioeconomy, ensuring that the supply chain is efficient and adaptable to future challenges.

Applied Research, Development, and Demonstration

Translation of foundational knowledge into emerging commercial applications will leverage transdisciplinary research. Public/private partnerships will be key to success in optimizing biomass supply system performance and reducing risk for investors and practitioners across supply chains. For example, demonstration of feasibility as a step towards adoption of climate-smart agricultural and forest practices will create the impetus for behavior changes of producers, processors, communities, consumers, and investors, thus contributing to economic growth from resilient supply chains.

Data Standardization and Integration

Standardizing data across feedstock sources and regions ensures consistency, transparency, and the efficient application of tools like LCA and TEA. In turn, this supports the development of densification

and pretreatment technologies and the efficient collection and conversion of biomass, as outlined in Deliverable 3. Reliable data streams also enable stakeholders to make informed decisions, driving transparency and transdisciplinary collaboration throughout all deliverables. In addition, these efforts are vital to securing the U.S. bioeconomy by facilitating domestic production of critical chemicals and materials, reducing reliance on foreign sources.

Workforce Development

As proposed in Deliverable 1, creating partnerships between educational institutions and industry to train a workforce skilled in biobased technologies will be critical to ensuring the workforce can handle the diverse demands of biomass collection, conversion, and feedstock production. This is especially important for maintaining U.S. leadership in producing bio-based critical chemicals, biofuels, food and medicines to that the country can respond to current and emergent national needs. Without a skilled workforce capable of implementing new technologies, supply chain resilience cannot be fully realized.

Responsible Innovation and Risk Communication

As discussed in the call for integration of economic and environmental data and models in Deliverable 3, risk communication tools help stakeholders assess potential environmental and economic impacts. Responsible innovation for supply chains encourages reallocating existing resources, such as repurposing idle infrastructure described in Deliverables 2 and 3, which both minimizes risk and promotes sustainability in developing new biomass commodity markets.

Conclusion

A resilient biomass supply chain is essential for the rapid growth of the bioeconomy. It is important to recognize that each of the links in the chain are connected and that the system will fail when the weakest link breaks. For example, new biomass crops can be developed but if there are no companies ready to use them in conversion processes or if there is not a market for these materials, the system will not develop. As a result, it is important for the key deliverables here to be developed in tandem and with open and transparent communication among the teams advancing the different deliverables, so that both the individual links and the connections between the links are strong.

Authorship and Acknowledgements

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References

Sources accessed on October 8, 2024

1. Building a Resilient Biomass Supply: A Plan to Enable the Bioeconomy in America. U.S. Department of Agriculture. https://www.usda.gov/sites/default/files/documents/biomass-supply-chain-report.pdf.
2. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022. U.S. Environmental Protection Agency. https://www.epa.gov/system/files/documents/2024-04/us-ghg-inventory-2024-main-text_04-18-2024.pdf.
3. Where greenhouse gases come from. U.S. Energy Information Administration. https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions.
4. Sustainable Aviation Fuel Grand Challenge. Department of Energy. https://www.energy.gov/eere/bioenergy/sustainable-aviation-fuel-grand-challenge.
5. The White House. (2022) Executive Order on Advancing Biotechnology and Biomanufacturing Innovation for a Sustainable, Safe, and Secure American Bioeconomy.