Vision Statement: Aligning Toward a Circular Bioeconomy

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Bioplastic Feedstock Alliance

About BFA

Convened by World Wildlife Fund (WWF), the Bioplastic Feedstock Alliance (BFA) was formed in 2013 as a multistakeholder initiative dedicated to a sustainable vision for biobased plastics. WWF organizes thought leadership in the biobased and biodegradable plastic space to support the shift away from fossil-based plastic and toward the increased conservation of the world's most precious ecosystems and protection of communities and livelihoods.

I. Introduction

A bioeconomy—an economy where goods are made from responsibly sourced biomass[i]—aims to contribute responsible, renewable resources to supply the materials, products, and fuels we rely on. In a linear, extractive scenario (take-make-waste), waste is created at a rapid rate, coming at a cost to biodiversity, ecosystems, the economy, and people.[1] Already, there have been substantial efforts and progress made by businesses, governments, and the public in transforming to circular systems. Now, BFA envisions an alternate scenario for the future where widespread circular systems maximize the value of all sectors, and where systems rely on renewable biobased resources (derived from plants, animal products, biogenic sources, or biogenic processes) rather than fossil fuels.

This vision statement builds on existing efforts to define a circular bioeconomy and explores how principles of a bioeconomy and circular economy can be integrated by seeking alignments for actors across sectors and industries. In this future scenario, a circular bioeconomy has a role to play, along with other approaches, to create a future in which people and nature thrive. We outline a vision of continued transformation from an extractive economic scenario to a circular bioeconomy, integrating circularity and recognizing the complexity of shared biobased feedstocks across sectors and applications. Although this paper sets forth a vision for a circular bioeconomy, we recognize a circular bioeconomy is not an end in itself or the only strategy available for contributing to the well-being of people and nature.

The vision established in this paper draws on tangible system principles found in both a circular economy and a bioeconomy:

- **Reduction in non-renewable resource consumption** by moving from a linear take-make-waste economy to a system where products and materials are designed to be reused, recycled, and recovered (r-imperatives).
- **Use of renewable biomass as inputs** that meaningfully contribute to reducing greenhouse gas (GHG) emissions and do not involve significant negative impact on freshwater, forests, biodiversity, soil health, or food security.
- **Conservation of nature and biodiversity** by adopting practices that restore natural habitats, enhance ecological diversity, and promote resilient ecosystems.
- **Promotion of a just transition** that is inclusive, is equitable, and brings positive social and economic outcomes to local communities.

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i Biobased feedstocks must be responsibly sourced to ensure they benefit the planet, the economy, and people: Feedstocks & Responsible Sourcing | Bioplastic Feedstock Alliance.

Although these economic systems are aligned in principle, in practice specific effort is needed to avoid conflicting incentives of biobased and circular systems and to achieve mutually beneficial outcomes. For example, the European Commission's Circular Economy Action Plan and Bioeconomy Strategy focus on each concept separately without fully exploring the possibility of aligning the two. The Bioeconomy Strategy overlooks r-imperatives (reduce, reuse, recycle, etc.) and closing material loops, and the Circular Economy Action Plan overlooks the potential of biobased materials by focusing on nonrenewable, abiotic resources.[2] Collaboration, alignment, and integration across sectors, industries, and civil society are key for an effective transition.[3] The unified vision for a circular bioeconomy set forth in this vision statement imagines all sectors and regions aligned and taking action to realize a responsible bioeconomy.

The biosphere and technosphere

Traditionally, the biosphere (value recirculates using biological processes) and technosphere (value recirculates using technological processes) are presented as separate cycles. But circular and biobased economic strategies should integrate the biosphere and technosphere so that the value of resources might be able to cross from one sphere to the other for value recovery. An example is bioplastics that cannot be cycled through the biological cycle (biosphere) but that can be recovered in the technosphere.

Source: Bioplastic Feedstock Alliance

II. Establishing a Common Understanding of a Bioeconomy

Many working definitions exist for a bioeconomy, adding complexity to collaborations across countries and sectors where alignment is needed to maximize benefits. Instead of aligning on a single definition to establish common understanding, aligning on principles and criteria could bring cohesion so that implementation of circular bioeconomy plans is effective. Presently, individual sectors (e.g., forestry, materials, energy) each have criteria and indicators, which vary regionally as countries adopt different working definitions. If these indicators and criteria are summed for an international bioeconomy approach, this results in compounding complexity for evaluating approaches and monitoring progress.

In 2021, the International Sustainable Bioeconomy Working Group led by the Food and Agriculture Organization (FAO) agreed on 10 principles and 24 criteria "to mainstream [...] across all economic sectors."[4] And in September 2024, the G20 reached consensus and published *G20 High-Level Principles on Bioeconomy*.[5] These efforts demonstrate that while it may not be possible to create a detailed, universal definition for a bioeconomy, it may be realistic to work toward a universal framework—with robust principles and indicators—that provides guidance to the implementation of an integrated circular bioeconomy. This framework, when applied regionally or in a sector or industry, should lead to positive outcomes for people, economy, and planet. Cooperation across norm-setting initiatives could be particularly useful to address this complexity and establish a common definition that aligns key actors. **BFA aims to leverage this vision statement by adding private sector and nongovernmental perspectives to the existing body of work and convening with others to contribute to common principles, indicators, and criteria**. These principles, indicators, and criteria would promote the use of circular economy principles that maximize positive outcomes in bioeconomy strategies, as outlined in Section III.

Bioeconomy definitions

There are several definitions proposed for a bioeconomy. See below for some examples.

In 2018, the International Advisory Council on Global Bioeconomy proposed a general definition: "The bioeconomy is the production, utilization and conservation of biological resources, including related knowledge, science, technology, and innovation, to provide information, products, processes and services across all economic sectors aiming toward a sustainable economy."[6]

In 2024, the United Nations Environment Programme describes it as follows: "In summary, the bioeconomy encompasses the bio-based economy and the development, utilization and production of food, feed, energy and related products."[7]

The European Commission understands the bioeconomy as "All sectors and associated services and investments that produce, use, distribute or consume biological resources (animals, plants, micro-organisms, including organic waste), including ecosystem services."[8]

III. Applying Circular Principles to Bioeconomy Strategies

Principles of bioeconomy and circular economy approaches are well established and have been adopted in national strategies globally.[2][9] Here, we present what is possible in each economic system before presenting our vision of an integrated circular bioeconomy.

The circular bioeconomy

The nova-Institute considers the circular bioeconomy as the intersection of bioeconomy and circular economy.[10] In this paper, we specifically set forth a vision for integrating specific circular principles with bioeconomy strategies, as described in this section.

What is possible with a circular economy?

Circular economy approaches play a central role in advancing climate and biodiversity objectives while respecting planetary boundaries.

The transition to circularity has the potential to transform the way materials and products are used. The principles of a circular economy—reducing consumption, avoiding waste and pollution, recirculating materials, conserving nature[ii]—inform decision-makers and guide cross-sectoral transitions to achieve positive outcomes such as adding economic value without extracting additional resources.[11][12]

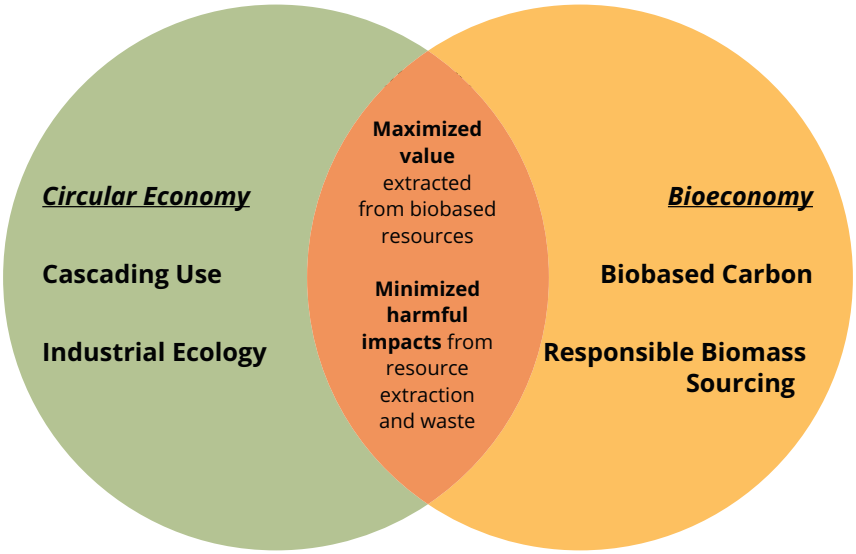
What is possible with a bioeconomy?

A bioeconomy offers solutions to mitigate environmental impacts and improve feed-stock supply security by replacing fossil carbon with responsibly sourced renewable resources.

Bioeconomy strategies entail the development, use, and production of renewable and responsible biobased materials, energy, and related products. It typically includes concepts like energy efficiency, emissions reduction, renewable practices, health and well-being, and product transformation.[7]

ii At the global level, national planning frameworks—such as 30x30 plans under Target 3 of the Kunming-Montreal Global Biodiversity Framework—can advance global conservation action.

Below is our version of the overlapping circular and bioeconomy Venn diagram put forth by others.[iii] In this diagram, we identify four concepts that are key to integrating the two systems.



It is our vision that circular concepts be applied more directly to a bioeconomy to amplify positive outcomes and overcome inefficiencies. Taking circular concepts and applying them to bioeconomy strategies provides a comprehensive, systematic approach. Of course, concepts from either can be applied to other sectors and industries. The concepts we identify are expanded on in the box below, and a discussion of an integrated circular bioeconomy follows.

iii Such as the work of Tan & Lamers (2021) and Pursula & Carus (2017). [10][29]

Cascading Use: The Cascading Use Principle creates the highest-value use for materials and adds value in the circular economy. In a Cascading Use system, a resource is consecutively processed into new products as its quality decreases. The best use of resources from both a climate and a nature perspective is in natural ecosystems and following the Cascading Use Principle, which prioritizes low-carbon, low-impact biomass where biomass is allocated to the most valuable uses at each stage and recycled for as long as possible.

In 2016, WWF convened the Cascading Materials Vision to develop guiding principles. WWF also completed a mapping study with partners on cascading use of wood products in six countries.[iv]

Biobased Carbon: The transition from fossil carbon to biobased carbon makes it possible to shift to more resilient economic models less dependent on fossil fuels if integrated globally and aligned across sectors. In that sense, biobased carbon and a bioeconomy has a greater mitigation potential over fossil-based carbon and the business-as-usual economy—a bioeconomic transformation is a key lever for achieving a 1.5°C pathway that supports the transition to a net zero emissions world by 2050. Circular principles applied in the framework of a bioeconomy help build resilience to the impacts of climate change for communities and landscapes.

Industrial Ecology: One tool in the transition to a circular economy is industrial ecology, where entities within industry are connected to each other, effectively closing production loops.[13] That is, the energy, water, material, or other by-product of one industry serves as the input to another. This approach eliminates waste, increases resource efficiency, and enhances industrial network collaboration.

Responsible Biomass Sourcing: To reach a future where both people and nature thrive, biobased resources should be made from responsibly sourced biomass feedstocks, maintain natural capital, and be produced in a way that benefits communities and supports resilient and thriving ecosystems and landscapes. For example, nature-based solutions and responsibly managed land and marine ecosystems support the protection of natural ecosystems, respect sustainable yield limits, and enhance ecosystem resilience.[8] Responsible sourcing principles apply to other industries as well, such as paper and metal.

In the context of a bioeconomy, industrial ecology maximizes the value extracted from biobased resources by reusing, recycling, or composting biomass waste materials and converting them into products.[14] By rethinking industrial models and applying the concept of industrial ecology, we can avoid waste by turning biological waste streams into valuable by-products. At Kalundborg in Denmark, an often-cited example of industrial symbiosis, the resulting biomass from fermentation at a biotech company serves farmers nearby.[15] Ultimately, taking a circular approach unlocks the use of biomass residues and wastes from the agriculture, food processing, and biobased industries.

iv The report, *Mapping Study on Cascading Use of Wood Products*, commissioned by WWF and global packaging and paper group Mondi, looks at how regulation either hinders or promotes what is known as "cascading use" of wood. Cascading use of wood products | WWF

In a circular bioeconomy, any Cascading Use framework should include principles for transparent decision-making that clearly articulate how biomass use addresses community needs while minimizing harmful impacts. Establishing a hierarchy for priority use of biobased resources can provide clarity and guidance so policymakers, businesses, and other actors can make informed decisions that balance the competing demands of food security, energy production, environmental protection, and economic development across a bioeconomy.

Resources should be put to good use—repaired, reused, recycled—as long as possible before finally being recovered for energy.[2] This means working to reduce absolute consumption of resources and prioritizing biomass for long-term material uses over energy uses wherever possible. By explicitly integrating a circular economy's r-imperatives into bioeconomy plans, we can keep biobased products in circulation for longer, with valuable materials remaining within the economy for longer before becoming waste. This requires designing products and materials for reuse, recycling, and recovery to close consumption and production loops. **Tightening consumption and production loops for biobased products reduces the demand for virgin biomass resources, which in turn offers the opportunity to minimize upstream harmful impacts from raw material extraction and downstream impacts from waste.**

A circular bioeconomy is not an end in itself, and biobased resources are not inherently better than other alternatives. Circular bioeconomy strategies may have trade-offs to consider or unintended consequences to explore, and measures must not come at the expense of community well-being. Although this vision statement presents a path for integrating circular principles into bioeconomy strategies, we acknowledge these strategies should be application specific. Strategies that take a place-based approach can assess which solution is best for a given application and context. For example, in certain regions, the burning of primary woody biomass is necessary to provide fuel for cooking and energy, whereas another region would use primary woody biomass for materials in a cascade before burning it for fuel and energy. In the aim to create a future in which people and nature thrive, all solutions should be considered. Ultimately, by adhering to thoughtful principles (e.g., G20 High-Level Principles on Bioeconomy), a circular bioeconomy can create lasting value for present and future generations and can help enhance social equity and foster inclusivity. In doing so, a circular bioeconomy can provide socioeconomic benefits for growing populations while reducing resource consumption.

IV. Defining Success

Biobased materials—inclusive of bioplastic, biofuels, and biochemicals—should contribute to a responsible, resilient system that supports people and nature. The transition to a circular bioeconomy across regions and applications will require feedstock supply, biorefineries, raw materials and processing technologies, and other supporting infrastructure, as well as policies to stimulate research, investments, and public support. Aligning cross-sectoral perspectives avoids siloed strategies and creates opportunities for collaboration.

Achieving an integrated circular bioeconomy means using biobased resources responsibly to fill the need for critical new input in a circular economy. Reaching this state contributes to positive outcomes, reduces negative impacts, and creates opportunities specific to the overlap of circularity and a bioeconomy. In the following table we list those opportunities and acknowledge the challenges we must address. Discussion follows on overcoming these challenges through meaningful collaboration.

Challenges exist in creating alignment across regions and key actors as well as in integrating circularity concepts with a bioeconomy. If we achieve an aligned, informed approach that considers everything for which we use biobased feedstocks, we can realize several socioeconomic and environmental opportunities.

Challenges	Opportunities
Future supply of responsibly sourced biomass: • **Competing demand for biomass and land** is an ongoing debate. • **Scaling responsible production** is necessary to avoid unintended consequences and maximize benefits from scaling biomass supply for use in many sectors. **Complexities developing strategies for joint effort:** • **Current strategies have limited scopes that may shift harmful impacts** from one lifecycle stage (e.g., biomass sourcing) to another (e.g., end of life treatment). • **Any strategies developed in isolation** may miss the full landscape and lead to "sustainability tunnel vision."[9] Narrow views of environmental and socioeconomic issues can limit progress in implementing plans.	**Build economic and landscape resilience** by responsibly managing natural resources like forests and fisheries while supporting local livelihoods. **Relieve demand on biomass through resource efficiency** using the Cascading Use Principle (p. 7) to assess the highest-value use of renewable biomass. **Create enabling conditions for successful carbon management** by scaling biomass systems and processes that sequester carbon and achieving GHG emissions by replacing fossil-based inputs with low-carbon biomass across applications.[16] **Make informed decisions** that consider the full demand—and which parts of what feedstock contribute to which products—for the major types of biobased feedstocks (e.g., agricultural, forest, seaweed and algae, residues and waste).

V. Overcoming Challenges of Integration and Alignment

To achieve the benefits of a circular bioeconomy, we need to overcome the listed challenges. In this section we further discuss the challenges, focusing on progress already made and highlighting different perspectives. In the final section, we call on key actors and make recommendations to build common ground for public and private sector plans alike.

Addressing Competing Demand

Competing claims on biomass and land resources for food, feed, fiber, and fuel production, along with the potential impacts on food security, environment, and biodiversity, can be major obstacles to building a future where people and nature can thrive. However, it is possible that multiple sectors using the same supply could allow for higher flexibility in the face of market fluctuations, which would grant economic resilience to regions producing biomass with varied applications.

It is important that we align on a methodical, principled approach to deciding hierarchies of use and set policy incentives to support them. Adopting responsible practices and land-use plans and grounding those in regulatory frameworks are essential to balance land-use demand and ensure the preservation of ecosystems and resources.[7] The efficient use of resources in a cascading system, where residues and recycled content are used, stretches total supply of biomass by prolonging the time a unit of biomass stays in use before new resources have to be extracted.[16]

Policy frameworks

The UK's Biomass Policy Statement sets principles and a biomass priority use framework for the short (2020s), medium (2030s), and long terms (2050).[17]

The EU's Renewable Energy Directive (RED) contains provisions to protect forest biodiversity and carbon stocks and establishes that woody biomass has to be used for its highest economic and environmental value rather than for energy.[18]

Several future scenarios exist with different predictions and recommendations for achieving sufficient biomass supply. Multiple entities have modeled future scenarios—U.S. Department of Energy [19], nova-Institute [20][21], Energy Transitions Commission [16]—that make varying predictions and recommendations for meeting future biomass demand. Uncertainty about future biomass supply and the effect this would have on feedstock cost presents challenges for the private sector. As mentioned above, though, multiple sectors using the same biobased feedstock could lead to more reliable supply that improves the ability of governments and corporations to develop circular bioeconomy strategies and steady demand that could reduce feedstock costs over time.

Scaling Responsible Production

As demand for biomass continues to grow, the potential for an increase in responsible production is limited by ecological factors, including the need to protect land and biodiversity. A circular bioeconomy must create space for biodiversity to thrive by conserving at least 30% of lands, inland waters, and oceans worldwide and reducing the use of primary biomass sources (wood and crops) for energy production by 50% by 2030.[22] A circular economy for biobased materials also presents opportunities to improve climate change adaptation and resilience through promoting ecosystem restoration and soil management, supporting Indigenous and local livelihoods, and building more responsibly managed forests and fisheries. Cooperation from the private sector (e.g., signaling demand) and the public sector (e.g., encouraging responsible sourcing) is needed to scale production in a way that is sustained into the future for people and nature.

Responsible sourcing frameworks, including voluntary standards as well as assessment methodologies,[v] align industries on management practices that protect and restore the quality of various indicators. Certain indicators—such as soil, water, and biodiversity quality—could in turn lead to increased yield efficiency so that we can do more while creating space for biodiversity and nature to thrive. Using consistent frameworks also makes it possible to assess, measure, and track potential impacts over time.

While bioresources are renewable, they are limited by available land and regeneration rate and are subjected to seasonal and climatic fluctuations—though capacity and productivity can be increased over time, as discussed above, with responsible sourcing principles that improve land stewardship (e.g., water, soil quality) for agricultural feedstocks. **Impacts on regeneration should be considered when determining the demand for biomass and whether there is enough supply to responsibly replenish a circular economy with biobased resources**. An integrated approach, taken across industries, considers these competing demands for informed decision-making.

Using Full Lifecycle Thinking

Though many companies, governments, and consumers are already working to reduce overall consumption and improve circularity, new inputs will still be required to meet critical needs. Biobased resources can fill this need for new inputs by replacing fossil carbon with renewable carbon. **However, biobased resources are not inherently better than fossil-based resources simply by virtue of being biobased—they must be responsibly managed throughout their lifecycle**.

Land, forests, and oceans provide innumerable ecosystem services and are particularly vulnerable in certain regions to tipping points.[23] Since a bioeconomy relies on numerous industries—like agriculture, forestry, aquaculture—that can be resource and land intensive, careful decision-making and responsible sourcing are necessary for the production and management of bioresources. As noted earlier, extraction of natural resources poses risks to biodiversity, soil health, water quality, and more. Other issues related to feedstocks include food security, land competition, water, climate

v Responsible sourcing standards (e.g., Roundtable on Sustainable Biomaterials) and methodologies (e.g., Bioplastic Feedstock Alliance's *Methodology for the Assessment of Bioplastic Feedstocks*) can protect and restore ecosystem function by mitigating impacts to metrics like water quality, land use change, chemical use, and more.

change, biodiversity loss, safe labor practices, and overall environmental and social performance.[vi] Responsibly managing biobased resources extends to end of life, where biobased products must be paired with compatible local infrastructure so that their value can be recovered and used consecutively. Presently, recycling and composting infrastructure is not adequately scaled at the local level in many geographies. Public-private partnerships and investments, along with supportive policies like Extended Producer Responsibility, are necessary to improve the recovery of bioplastics as part of a circular bioeconomy.

Recirculating bioresources for maximum value

To successfully integrate with a circular economy, products of a bioeconomy can and should be recirculated, through either reuse, recycling, composting, or other viable means of recapturing value. An example is a biobased material like wood being used in construction first, then repaired and reused as many times as possible before being recycled into plywood and later being used as pulp for paper products before being recovered for energy. See footnote iv for WWF and Mondi's *Mapping Study on Cascading Use of Wood Products*.

Developing Strategies for Joint Effort

Economic strategies developed in isolation will have a narrow view of the environmental, social, and economic landscape. This limited view may lead to an overemphasis of industry solutions (e.g., bioenergy) and sustainability issues (e.g., carbon footprint), which may neglect potential benefits and risks in renewable resource supply chains. Particularly, by working in isolation, decision-makers could miss opportunities beyond the boundaries of a circular economy to maximize resource use, avoid waste, and make their economies resilient in the face of fluctuating biomass demand. Alternatively, they could cause unintended consequences by focusing too heavily on one indicator without considering trade-offs. For example, in the energy sector, a narrow focus on a bioeconomic strategy as a tool to reduce reliance on fossil fuels means the use of biomass for energy could be viewed favorably. However, alternate solutions outside the bioeconomy, such as the commercialization and scaling of renewable electricity sources, could contribute to defossilization while reducing competing demand for bioresources. Being too focused on a circular bioeconomy could limit the range of technologies considered for a given application and ignore the possible combination of solutions available to shift away from a linear economic system dependent on the extraction of nonrenewable resources. Any circular bioeconomy approach must also consider and evaluate alternate solution sets before identifying the best path forward.

Additionally, there is risk to countries operating in isolation when developing national bioeconomy strategies, especially since countries prioritize different economic indicators (e.g., GDP, employment) and different economic sectors (e.g., agriculture, forestry, manufacturing).[9] But this approach could overlook regional collaboration, where knowledge sharing and expanding industrial ecosystems could amplify benefits and create synergies when compared to operating in a silo (e.g., residuals from one sector, like agriculture, are feedstock for another, like energy, and could exist across borders).

vi These are issues BFA explores and provides expertise on: Bioplastic 101 | Bioplastic Feedstock Alliance.

Compounding complexity in monitoring progress

In 2021, all G20 and Organisation for Economic Co-operation and Development member states with bioeconomy strategies were invited to workshops on the objectives, gaps, and opportunities of their strategies. The resulting paper highlights how quickly the number of indicators proliferate (e.g., 60 economic indicators in Germany alone) as countries attempt to implement monitoring systems that would be able to assess progress related to bioeconomy strategies.[9]

Similarly, businesses could benefit from using a broader industrial network view. Multiple product supply chains may demand similar or the same feedstocks, presenting a key opportunity for cross-sectoral products and collaboration. For example, in the food industry, unavoidable food waste from food processing tends to be more homogeneous than consumer food waste.[24] In this example, companies in the food industry can work together to identify and deliver biomass that is easier to process from waste streams efficiently and effectively.

VI. Recommendations for Key Actors

We can develop a circular bioeconomy that contributes to a more just and resilient future for society and the planet by adopting a holistic strategy that considers all aspects of biomass resource utilization. A circular bioeconomy must be collectively envisioned, developed, governed, and financed as a cohesive and unified system.[25] This involves actions from key actors to establish coherence and alignment among the sectors involved to drive positive outcomes. It requires implementing integrated, landscape approaches that ensure equity in the development of bioeconomy-related products and services, as well as balancing multiple goals and avoiding trade-off impacts. The section below provides recommendations for the following key sectors: Public Sector Policymakers, Businesses, Nongovernmental Organizations (NGOs), and Financial Institutions.

Public Sector Policymakers

Policy considerations will be significant in developing a circular bioeconomy. Embedding strong governance and cooperation at local, national, and international levels increases synergies and the likelihood that policymakers set consistent criteria across diverse policy areas.[8] This may begin with defining framework-setting instruments and creating guiding principles that demonstrate the need for action at different levels for implementation of measures and for achieving targets. Action strategies should contribute to overarching environmental goals such as climate change mitigation and biodiversity conservation. Policy already greatly affects the use of biomass, where it led to a 150% increase in bioenergy use in the EU in the past two decades, though often without directing biomass use toward the highest-value uses.[26] By implementing thoughtful and comprehensive policy frameworks, governments can create an enabling environment for the development of a circular bioeconomy.

Public sector policymakers can advance circular bioeconomy solutions by:

- **Adhering to international definitions and/or indicators** to track progress in implementing circular bioeconomy plans, such that measuring and monitoring methods are comparable and can be tracked globally.[9]
- **Ensuring consistent outcomes-based policy** across economic sectors by collaborating and sharing knowledge to build agendas for joint action and lessening the load to individual countries' capacities.
- **Striving for environmental policy agenda coherence** across different regions so that policies are aligned to achieve the same or similar outcomes.
- **Fostering civil society support** by identifying and communicating social benefits created through the development of a circular bioeconomy.
- **Implementing a use hierarchy decision framework for bioresources** and aligning policy incentives to this hierarchy that maximizes the value from bioresources at each stage of use.
- **Enabling consistent operating frameworks** with clear methodologies that standardize understanding and incentivize investments to catalyze a circular bioeconomy at a value chain level.
- **Establishing funds for circular and bioeconomy research and industrial networks** that close production loops and inform national decarbonization and bioeconomy plans (e.g., USDA's National Institute of Food and Agriculture's Bioproduct Pilot Program).
- **Creating measures that endorse innovation and research** for biobased and circular activities (e.g., technological material, energy, resource efficiency) and that develop new knowledge and skills of employees in political offices (e.g., data collection, reporting of circular bioeconomy indicators).
- **Leveling the playing field for bioresource applications** by setting measures that ensure decision-makers consider the highest-value use cases and make transparent decisions.
- **Enhancing material circularity** by fostering enabling conditions and establishing supportive public policies for upstream, midstream, and downstream segments.[27]

Businesses

Businesses are key drivers of circular bioeconomy development. They are able to assess sourcing and check that responsible practices are being pursued in the supply chain. Businesses also recognize that implementation of responsible sourcing practices is a complex process that varies across industries and feedstocks. Transparency and credibility in these areas will benefit biobased industries' credibility with the public and can positively inform responsible sourcing and consumption practices as systems scale.

Businesses can advance circular bioeconomy solutions by:

- **Participating in cross-industry collaboration** that aggregates industry data (e.g., supply chain) in a way that improves market knowledge and facilitates informed decision-making.
- **Leveraging their supply chain**—by creating internal sourcing policies, specifying design requirements, and choosing preferred suppliers—to create alignment in their value chain and amplify positive outcomes (e.g., reduced emissions, resource consumption).
- **For new operations, co-locating operations** that are connected in the principles of industrial ecology to reduce negative outcomes (e.g., waste, pollution) and improve positive outcomes (e.g., logistics efficiency).
- **For existing operations, creating networks** with industrial ecology principles with local partners and sharing logistic resources or infrastructure to exchange materials and waste.
- **Advancing technological innovation** that integrates circular and bioeconomy principles and that improves efficiency, reducing the demand for bioresources (e.g., materials, energy).
- **Adopting robust sustainability metrics and reporting mechanisms** (e.g., regional regulations, voluntary certification schemes) to enhance transparency and accountability in biobased and circular production and supply chains, fostering trust with consumers and stakeholders.

Nongovernmental Organizations

Nongovernmental organizations contribute to the transition by convening actors, advancing thought and innovation, and developing standards and frameworks. NGOs can both be central components by acting as hubs for knowledge creation and sharing and be accelerators for credible action by developing standards and monitoring programs.

NGOs can advance circular bioeconomy solutions by:

- **Generating technical knowledge** that aims to understand unintended consequences, balance trade-offs, and realize full benefits that aids both the private and public sectors to align on hierarchies for highest-value uses.
- **Convening cross-sectoral and multi-industry stakeholders** in formal knowledge sharing opportunities to accelerate technical breakthroughs and systemic improvement.
- **Developing criteria, principles, and frameworks** that are applicable across industries so that environmental and economic activities are aligned with circular and bioeconomy principles.
- **Developing, promoting, and monitoring certification schemes** based on harmonized sustainability indicators and criteria to enable verification and increase scientific certainty.
- **Engaging in policy advocacy and collaboration** to foster comprehensive bioeconomy strategies that lead to consistent bioeconomy policies, align industry growth with policymakers' bioeconomy strategies, increase public awareness, and foster supportive financial frameworks.

Financial Institutions

It is estimated that the current global value of the bioeconomy is US$4-$5 trillion and has the potential to grow to US$30 trillion by 2050.[25] Financial institutions (e.g., asset managers, multilateral development banks) can provide incentives and demand signals to companies that operate in a bioeconomy and circular economy. By mobilizing funds, the financial sector can de-risk investments in technology, innovation, and infrastructure that develop a circular bioeconomy.

Financial institutions can advance circular bioeconomy solutions by:

- **Committing to investments** in a bioeconomy and circular economy.
- **Disclosing lending and investment** in economic activities so it is transparent if financing is related to a bioeconomy and circular economy or to a fossil-based economy.
- **Adopting the same principles and criteria** as other sectors to create alignment and consistency that instill confidence in decision-makers by adhering to the same standards.
- **Promoting the use and adoption of sustainability standards and frameworks** for certification to provide assurances in their investments.
- **Supporting and underwriting innovative finance solutions** like venture capital, green bonds, and sustainability-linked loans for biobased and circular economic activities. Blended public-private financing can further support these efforts, especially in lower-middle income countries.[28]
- **Supporting the scale-up of circular bioeconomy initiatives** by mobilizing capital to de-risk investments in technology, innovation, and infrastructure, particularly for hard-to-abate sectors.
- **Equitably distributing economic benefits** where benefits of the transition to circular bioeconomy models at the macroeconomic scale may be unevenly distributed.
- **Encouraging participation** in NGO-organized convenings by promoting thematic opportunities to their networks.

VII. Conclusion

The vision established in this paper can support the transformation toward an economy that integrates biobased feedstocks and circularity principles while recognizing the complexity of shared feedstocks and systems across sectors and applications. Establishing this common vision is the first step to creating cross-sector and industry integration—the recommendations for key actors in this paper aim to overcome silos through collaboration and alignment to fill gaps in visibility and decision-making. This alignment overcomes challenges and creates a complementary, synergistic, integrated web of economic regions and activities that amplify positive social, environmental, and economic outcomes. We recognize that the recommendations in this paper are high level. As a next step, these recommendations can be leveraged to facilitate cross-sector collaboration and enable the development of common criteria and strategies for joint effort to maximize the value of renewable biobased resources.

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