Available Online
Journal of Social Sciences Advancement
www.scienceimpactpub.com/jssa
DOI: https://doi.org/10.52223/JSSA26-070124

Bioeconomy Pathways for Sustainable Development in China: A Conceptual and Policy Review

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ARTICLE INFO

ARTICLE HISTORY
Received: December 21, 2025
Accepted: March 23 2026
Published: March 30, 2026

KEYWORDS
Bioeconomy;
Circular bioeconomy;
Sustainable development;
Bio-based materials;
Ecosystem services;
China.

ABSTRACT

This study examines how China's bioeconomy can contribute to sustainable development through a conceptual and policy-oriented review of key bioeconomic pathways. It develops an integrated analytical framework grounded in the Circular Economy, Ecological Modernization Theory, and the Sustainable Development Goals (SDGs) to assess the role of bioeconomic transformation in China's green development strategy. The paper identifies six major pathways: sustainable agriculture and food systems, forestry, ecosystem services, bioenergy, bio-based materials, and bio-based and eco-integrated cities. These pathways can support resource efficiency, carbon-emission reduction, rural development, industrial innovation, and ecological restoration when they are embedded within effective governance and circular resource-use principles. The analysis highlights that China's bioeconomy is increasingly supported by national policy frameworks, including the 14th Five-Year Plan for Bioeconomy Development, but also faces important trade-offs related to land use, biodiversity protection, biomass sourcing, lifecycle emissions, and regional implementation capacity. The study concludes that the bioeconomy should not be treated as inherently sustainable; rather, its contribution to China's sustainable development depends on policy coherence, environmental safeguards, lifecycle assessment, inclusive governance, and integration with broader SDG objectives.

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INTRODUCTION

The growing complexity of implementing sustainable development has intensified the demand for innovative and system-oriented solutions, particularly within the economic domain (Maciejczak, 2023). Rapid urbanization and industrialization have generated a wide range of interconnected challenges, including biodiversity loss, inefficient waste management, water depletion, rising energy consumption, food-system pressures, air pollution, land-use change, infrastructure deficits, and forest degradation (D'Amico et al., 2022). Moreover, the expansion of industrial and urban activities has contributed to improper waste disposal, creating environmental and public health risks (Karuppiah et al., 2023).

Within this context, the circular economy paradigm emphasizes resource efficiency, waste reduction, recycling, and the reintegration of materials into production and consumption systems. This shift highlights the relevance of the bioeconomy as a development pathway that can support sustainable economic transformation when it is designed around renewable biological resources, circularity, and environmental safeguards. Accordingly, the bioeconomy can be conceptualized as a model that integrates resource efficiency, environmental sustainability, technological innovation, and economic growth (Maciejczak, 2023).

In recent decades, sustainable development has gained substantial global attention due to the increasing urgency of addressing climate change, environmental degradation, and natural resource depletion (Slorach et al., 2019). Environmental losses now pose direct risks to economic stability, making it necessary to integrate environmental safeguards into economic activities (Khoshnevisan et al., 2020). At the same time, concerns regarding global warming and resource scarcity have encouraged the adoption of innovative production and consumption systems aimed at improving sustainability (Abad-Segura et al., 2021). In this regard, sustainable development refers to a model that satisfies present needs without compromising the ability of future generations to meet their own needs, while balancing environmental protection, social welfare, and economic growth (Abad-Segura et al., 2019; Stewart & Niero, 2018).

Sustainable development encompasses economic, social, and environmental dimensions, emphasizing the efficient and equitable use of resources. It promotes development strategies that meet current societal needs while safeguarding the rights and opportunities of future generations (Abdullah, 2024). The Sustainable Development Goals (SDGs), adopted by the United Nations as part of the 2030 Agenda, provide a comprehensive framework for addressing global challenges such as poverty, inequality, climate change, and environmental degradation. These goals serve as guiding principles for governments, organizations, and individuals in pursuing inclusive and sustainable development pathways (Kumar et al., 2024). Complementary global initiatives, such as the Paris Agreement and the European Union's climate-neutrality target for 2050, further reinforce the transition toward sustainable economic systems (Hoehn et al., 2021; Janssens et al., 2020; Sampedro et al., 2020).

The concept of the bioeconomy gained prominence in the early 2000s, particularly among institutions such as the European Union and the Organisation for Economic Co-operation and Development. The bioeconomy seeks to use renewable biological resources, biotechnology, and knowledge-based innovation to produce goods and services across economic sectors in a sustainable manner (Istudor & Suciu, 2020). It represents a transition toward an economic system that integrates biological resources, technological advancement, and sustainable production processes. As such, the bioeconomy has been linked to major global challenges, including climate change, food security, resource efficiency, and income diversification (Jander & Grundmann, 2019; Oláh et al., 2023). However, recent literature emphasizes that the bioeconomy should not simply replace fossil-based resources with biological alternatives. Instead, it must be intentionally designed as a circular and regenerative system; otherwise, it may reproduce unsustainable linear production patterns under a different resource base (Morone et al., 2026).

More specifically, the bioeconomy emphasizes the sustainable production, transformation, and use of biological resources for energy, materials, industrial products, food systems, and services. This model can draw on technological innovation, including digital systems, to improve efficiency in sectors such as agriculture, health, water management, energy, and environmental protection. By improving resource circulation and strengthening governance mechanisms, the bioeconomy can support both economic performance and environmental sustainability (Hahn, 2011; IACGB, 2020).

Despite its potential, the transition toward a bioeconomy is not inherently sustainable and remains associated with important challenges. Existing literature has often emphasized the environmental benefits of bioeconomic technologies while giving less attention to their broader social, ethical, and governance implications. In some cases, increased exploitation of biological resources may lead to ecosystem degradation, land-use conflicts, biodiversity loss, social inequalities, and pressures on water and soil systems (Oláh et al., 2023). These concerns highlight the need for a balanced and well-regulated approach to bioeconomic development, supported by effective governance, resource-efficiency principles, and sustainability safeguards.

In the case of China, rapid technological advancement, industrial transformation, and policy emphasis on green development have created significant opportunities for integrating bioeconomic strategies into sustainable development frameworks. China's 14th Five-Year Plan for Bioeconomy Development (2021–2025) provides an important policy basis for this transition by identifying the bioeconomy as a strategic area linked to biotechnology, biological breeding, biomaterials, bioenergy, medicine, agriculture, and related industries (National Development and Reform Commission, 2022). This policy direction reflects China's broader emphasis on innovation-driven growth, ecological civilization, and high-quality development. Consequently, the bioeconomy has become increasingly relevant to China's long-term sustainability agenda and to academic and policy debates on the transition toward greener development models (Pfau et al., 2014).

Against this background, this study addresses the following research questions: What bioeconomic pathways are most relevant for China's sustainable development? Why is the development of the bioeconomy important for achieving sustainability objectives? Which strategic approaches can facilitate China's transition toward a sustainable bioeconomy, and how can these approaches contribute to the achievement of the SDGs? To address these questions, the study develops a conceptual and policy-oriented analytical framework that examines key bioeconomic pathways in China, including agriculture and food systems, forestry, ecosystem services, bioenergy, bio-based materials, and bio-based urban development. The paper contributes to the literature by clarifying how these pathways can support sustainable development while also identifying the governance challenges and trade-offs that must be addressed for the bioeconomy to contribute effectively to China's sustainability transition.

Conceptual Framework

This study adopts an integrated bioeconomy–sustainability framework to examine how bioeconomic transformation can support sustainable development in China. The framework is developed in line with the study's research objectives and is grounded in three complementary perspectives: the Circular Economy, Ecological Modernization Theory, and the Sustainable Development Goals (SDG) framework.

The circular economy perspective emphasizes efficient resource utilization, waste reduction, recycling, cascading use of biomass, and the regeneration of biological resources. Within this perspective, the bioeconomy contributes to sustainability when biological resources and waste streams are reintegrated into production and consumption systems rather than used through linear extraction–production–disposal models (Maciejczak, 2023; Stegmann et al., 2020; Tan & Lamers, 2021). This perspective is particularly relevant for understanding the role of agricultural residues, forestry resources, biorefineries, and bio-based materials in reducing waste and improving resource efficiency.

Ecological Modernization Theory explains how technological innovation, institutional reform, and environmental governance can align economic growth with environmental sustainability. In the context of China, this perspective helps explain how state-led planning, innovation policy, and green industrial transformation support the expansion of ecological agriculture, renewable and bioenergy systems, bio-based industries, and eco-urban development (Acuto et al., 2020; Pfau et al., 2014). However, ecological modernization does not imply that all technological change is automatically sustainable. Its effectiveness depends on regulatory capacity, institutional coordination, and the extent to which environmental safeguards are embedded in development strategies.

The SDG framework provides a global policy structure for evaluating sustainability outcomes across environmental, economic, and social dimensions. It enables assessment of how bioeconomic pathways contribute to broader sustainable development objectives, including food security, clean energy, responsible production and consumption, sustainable cities, climate action, and biodiversity protection (Abdullah, 2024; Kumar et al., 2024). In this study, the SDG framework is used to connect China's bioeconomic pathways to specific sustainability outcomes rather than treating the bioeconomy as an inherently sustainable development model.

Based on these perspectives, this study proposes that bioeconomic pathways—including agriculture and food systems, forestry, ecosystem services, bioenergy, bio-based materials, and bio-based urban development—can contribute to sustainable development through three interconnected mechanisms. First, they improve resource efficiency by promoting circular use of biomass, waste reduction, and sustainable production systems. Second, they support carbon-emission reduction by substituting fossil-based inputs with renewable biological resources and low-carbon technologies where appropriate. Third, they can promote inclusive socio-economic development by supporting rural livelihoods, green employment, food-system resilience, and healthier urban environments. At the same time, these contributions depend on effective governance, because poorly regulated bioeconomic expansion may create new pressures on land, water, biodiversity, and local communities.

Analytical Approach

This paper adopts a conceptual and policy-oriented review approach. It does not conduct new empirical estimation; rather, it synthesizes relevant academic literature, policy documents, and selected China-focused examples to examine how bioeconomic pathways can support sustainable development. The pathways discussed in the paper are selected because they correspond to major areas of China's bioeconomy transition, including agriculture and food systems, forestry, ecosystem services, bioenergy, bio-based materials, and bio-based urban development.

The analysis proceeds in three steps. First, it uses the conceptual framework outlined above to clarify how the circular economy, ecological modernization, and the SDG framework relate to the bioeconomy. Second, it examines China's major bioeconomic pathways and their potential contribution to sustainability outcomes. Third, it identifies the main challenges and trade-offs associated with these pathways, including governance constraints, resource pressures, technological scalability, and the risk that bio-based development may reproduce unsustainable practices if circularity and environmental safeguards are not embedded in policy design. This approach allows the paper to assess the bioeconomy as a conditional pathway to sustainable development rather than as an automatically sustainable model.

Bioeconomy's Role in the Sustainable Development of China

Guided by the proposed theoretical framework, this section analyzes key bioeconomic pathways through which China can promote sustainable development across agricultural, environmental, industrial, and urban systems. In 2020, Xi Jinping announced at the United Nations General Assembly that China would aim to peak carbon dioxide emissions before 2030 and achieve carbon neutrality before 2060. This commitment represents an important shift in China's long-term development strategy, emphasizing the transition from fossil-fuel dependence toward cleaner energy systems, resource efficiency, and low-carbon industrial transformation. China's 14th Five-Year Plan for Bioeconomy Development (2021–2025) further strengthens this policy direction by identifying the bioeconomy as a strategic area linked to biomedicine, biological breeding, bio-based materials, bioenergy, and the broader development of bio-based industries (National Development and Reform Commission, 2022). Table 1 provides an overview of the major national policies and development plans that have shaped China's bioeconomy and its integration with broader sustainability objectives.

The bioeconomy has increasingly evolved from a narrow sectoral concept into a broader development paradigm that links economic growth, biodiversity conservation, technological innovation, and social inclusion. Different regions operationalize the bioeconomy in different ways. For example, OECD-oriented approaches often emphasize biotechnology, biomass utilization, and innovation systems, while some Latin American models place stronger emphasis on ecosystem services, territorial development, biodiversity, and traditional knowledge (Dietz et al., 2018; OECD, 2026). This variation highlights that the bioeconomy is not a single fixed model, but a policy framework that must be adapted to national development priorities, ecological conditions, and governance capacities.

A transition toward a circular bioeconomy enhances the value of biomass resources and waste streams by promoting their reintegration into production processes. While some scholars argue that the bioeconomy and circular economy are closely connected, the two concepts should not be treated as identical. The bioeconomy focuses on the use of renewable biological resources, whereas the circular economy emphasizes resource circulation, waste reduction, and extended material use. A sustainable bioeconomy therefore requires circular-economy principles to ensure that biological resources are used efficiently and within ecological limits (Stegmann et al., 2020; Tan & Lamers, 2021). Figure 1 summarises the conceptual relationship between renewable biological resources, circular production systems, technological innovation, governance safeguards, and sustainable development outcomes.

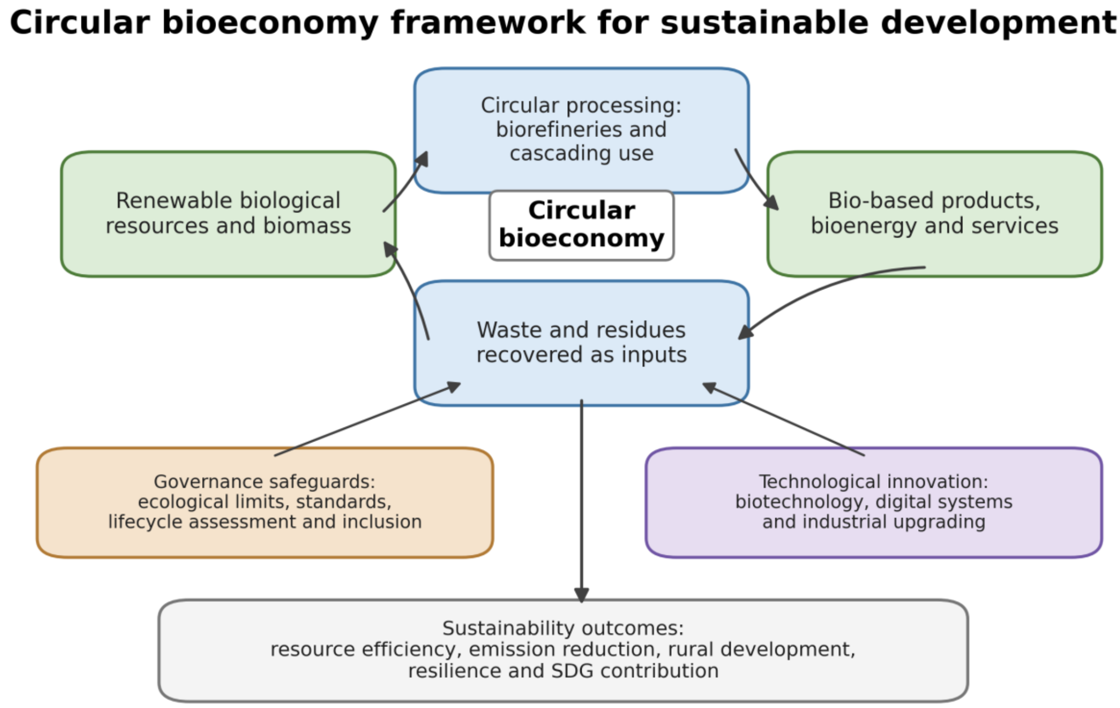

Figure 1: Circular bioeconomy framework for sustainable development

Note: The figure illustrates the circular bioeconomy as an integrated system in which renewable biological resources, circular processing, bio-based products, waste recovery, governance safeguards, and technological innovation interact to support sustainable development outcomes. The circular bioeconomy is not automatically sustainable. Its contribution depends on circular resource use, lifecycle assessment, ecological safeguards, inclusive governance, and technological innovation.

At its core, the bioeconomy involves the sustainable use of renewable biological resources for the production of food, energy, materials, industrial products, and services. A critical component of this transition is the development of decentralized and small-scale biorefineries, particularly at regional and local levels. These biorefineries can convert locally available biomass and biowaste into value-added products, thereby supporting rural development, reducing transportation costs, and improving resource efficiency (Panoutsou & Singh, 2020). For example, agricultural feedstocks and residues can be transformed into bioplastics, textiles, bio-based chemicals, and industrial lubricants, demonstrating the versatility and economic potential of bio-based production systems.

The successful implementation of bioeconomic strategies requires coordinated stakeholder engagement, investment in technological and industrial infrastructure, and supportive policy frameworks. In China, the transition toward a sustainable bioeconomy can be strengthened through ecological agriculture, sustainable forestry, biodiversity conservation, biorefinery development, bio-based materials, bioenergy, and bio-based urban planning. Policy initiatives aimed at developing bio-based and eco-integrated cities can further enhance urban sustainability when they are linked to circular resource management, green infrastructure, renewable energy systems, and inclusive urban governance (Uwe et al., 2021). Collectively, these strategies illustrate how the bioeconomy can contribute to

China's sustainable development by promoting innovation, resource efficiency, carbon-emission reduction, and environmental resilience.

Agriculture and Food

China has made significant efforts to implement sustainable agriculture and food-security policies in response to rising domestic demand, environmental constraints, and the need to improve resilience in food systems. Ensuring food supply for a large population requires efficient agricultural production, resilient supply chains, and policy frameworks that reduce environmental pressures from intensive farming and food production. In this context, strengthening supply-chain coordination, improving resource-use efficiency, and supporting farmers are central to the transition toward a sustainable agricultural bioeconomy. Policy priorities therefore include promoting environmentally sustainable agricultural practices, reducing waste, improving food safety, and establishing efficient and health-oriented food systems (Pulighe & Lupia, 2020; Rowan & Galanakis, 2020).

Ecological and bio-based agricultural practices play a critical role in facilitating the transition toward sustainable food systems. Urban agriculture can contribute to this transformation through rooftop farming, vertical farming, community gardening, and consumer-awareness initiatives. These approaches may reduce dependence on long-distance supply chains and lower transportation-related fossil-fuel consumption and emissions, particularly when they are integrated with local food systems and circular resource management (Fritsche et al., 2020). In addition, nutrition education, public procurement policies, and support for local and regional food systems can strengthen sustainable consumption patterns and facilitate the shift toward environmentally responsible agriculture.

Reforms in livestock management are also essential for advancing green agricultural transformation. The use of livestock manure as organic fertilizer can reduce dependence on synthetic chemical inputs, while improved feeding practices and circular nutrient management can contribute to the production of bio-based fertilizers, enhance soil fertility, and reduce environmental pollution. These practices reflect the broader role of agricultural modernization in supporting a circular bioeconomy. Furthermore, advancements in food processing, including the use of bioactive components and biotechnology-based innovation, represent emerging opportunities within the bioeconomy framework, particularly where they improve nutritional quality, reduce waste, and enhance food-system resilience (Fritsche et al., 2020; Rowan & Galanakis, 2020; Uwe et al., 2021). Given its structural importance, agriculture remains central to China's bioeconomic transition, encompassing major crops, minor crops, livestock, forestry, fisheries, and the valorisation of agricultural residues.

China has intensified its focus on sustainable agriculture to mitigate the environmental impacts of agricultural production and align rural development with national sustainability objectives. Empirical studies have highlighted ecological agriculture and agricultural ecological efficiency as important mechanisms for reducing environmental pressures and improving sustainability outcomes in China (Wu, Riaz, et al., 2022; Wu, Xie, et al., 2022; Yang et al., 2022). In policy terms, the National Sustainable Agricultural Development Plan (2015–2030) and the 14th Five-Year National Agricultural Green Development Plan (2021–2025) reflect China's continuing commitment to green agricultural transformation. These policy frameworks emphasize resource conservation, reduction in chemical fertilizer and pesticide use, improved utilization of livestock and poultry manure, agricultural waste recycling, and the modernization of rural production systems.

China's 14th Five-Year Plan for Bioeconomy Development further reinforces the role of agriculture in the national bioeconomy by identifying biological breeding, bio-agriculture, food security, and biotechnology-based innovation as important areas of development (National Development and Reform Commission, 2022). This policy direction links agriculture directly to broader bioeconomic objectives, including sustainable biomass use, rural revitalization, green industrial development, and improved resilience of food systems.

International financial institutions have also supported China's green agricultural transition. For instance, in 2022, the World Bank approved a loan of USD 320 million to support green agriculture and rural development in southwestern China. This initiative aims to reduce greenhouse gas emissions from agricultural activities, mitigate plastic pollution in rural production systems, and support China's broader rural revitalization strategy (World Bank, 2022). Such initiatives demonstrate how sustainable agriculture can contribute simultaneously to environmental protection, rural development, and food-system resilience.

Despite these efforts, further policy strengthening is required to accelerate the transition toward sustainable agriculture. In particular, China needs to continue developing regulatory frameworks that reduce the environmental footprint of agricultural production, minimize excessive reliance on chemical fertilizers and pesticides, promote climate-resilient farming systems, and strengthen circular use of agricultural waste and residues. These reforms are essential for ensuring that agricultural development contributes effectively to long-term environmental sustainability, SDG 2 on food security, SDG 12 on responsible production and consumption, SDG 13 on climate action, and the broader objectives of China's bioeconomy transition.

Forestry

Forestry represents a critical component of the land-use system and plays a significant role in the development of a sustainable bioeconomy. The expansion of the bioeconomy has increased the economic and strategic importance of forestry by raising demand for forest-based products such as paper, textiles, construction materials, chemicals, packaging materials, bioenergy, and other wood-based biomaterials. At the same time, forests remain essential for biodiversity conservation, ecosystem stability, carbon sequestration, and long-term environmental sustainability. Therefore, the utilization of forest resources must be governed by principles of sustainable forest management to ensure ecological balance, resource regeneration, and protection of ecosystem services (Wolfslehner et al., 2016).

Forests also play an important regulatory role in climate systems by supporting carbon storage, temperature regulation, hydrological stability, and ecosystem resilience. In addition, forest-based industries are increasingly producing alternatives to fossil-based and plastic-intensive products, including paper packaging, bio-textiles, engineered wood products, and sustainable construction materials. These developments can reduce dependence on fossil-based materials and support lower-carbon production systems when forest resources are harvested and regenerated sustainably.

Forestry contributes to the bioeconomy through three main channels: (i) the production of biomaterials, (ii) ecosystem protection and biodiversity conservation, and (iii) bioenergy generation. When managed sustainably, these channels can contribute to greenhouse-gas mitigation, rural economic diversification, and climate-risk reduction, including risks associated with flooding, soil erosion, and land degradation. However, these opportunities are accompanied by environmental risks if forest exploitation is not properly regulated.

Excessive reliance on biomass may increase pressure on forests and can undermine climate benefits if harvesting exceeds ecological carrying capacity or if forest carbon stocks are depleted. Unsustainable logging practices may also lead to deforestation, biodiversity loss, soil degradation, and long-term ecosystem instability. Therefore, forest-resource utilization must remain within ecological limits and be supported by robust governance systems. Sustainable forest management should balance economic use with environmental preservation, while afforestation and reforestation initiatives can play an important role in restoring degraded landscapes and enhancing carbon sequestration.

Globally, countries are increasingly prioritizing forest restoration, ecosystem diversification, and the development of wood-based materials in response to rising demand for renewable resources. Timber and other forest-based resources are now being used in innovative ways, including as substitutes for plastic packaging, insulation materials, and components in industrial manufacturing. These bio-based materials can contribute to reducing fossil-carbon emissions and environmental externalities, provided that their production is based on sustainable sourcing and lifecycle considerations (Wolfslehner et al., 2016). Effective regulation of wood supply is therefore essential for preventing overexploitation and ensuring that forest-based bioeconomy development remains aligned with sustainability objectives (Camia et al., 2021).

Afforestation and forest landscape restoration further contribute to sustainable development by providing biomass resources, supporting rural economic diversification, and strengthening ecological resilience. Trees play a dual role in rural and urban environments by improving air quality, regulating local temperatures, reducing flood risks, and enhancing landscape stability. In addition, forests provide nature-based solutions for carbon sequestration and environmental protection, thereby contributing to climate-change mitigation and ecological stability (Fritsche et al., 2020; Uwe et al., 2021).

In China, forestry is closely connected to the national agenda of ecological civilization. This concept places strong emphasis on governance systems, ecological integrity, and the balance between human development and nature (Hanson, 2019). In recent years, ecological civilization has become a central principle in China's environmental governance, including forest protection, ecological restoration, and land-greening policies. During the 14th Five-Year Plan period, China set targets to increase forest coverage, expand forest stock volume, strengthen grassland protection, and improve ecosystem restoration. Recent official reporting indicates that China's forest coverage reached approximately 25 percent by the end of 2025, reflecting continued expansion of national forest resources and land-greening initiatives (State Council of the People's Republic of China, 2026).

Overall, forestry has the potential to play a central role in China's transition toward a sustainable bioeconomy by enhancing ecosystem services, supporting green industrial development, expanding bio-based materials, and contributing to climate-change mitigation. However, realizing this potential requires comprehensive sustainable forest-management systems that regulate harvesting, prevent deforestation, promote reforestation, and expand urban forestry. In particular, increasing urban tree cover and integrating forests into urban and peri-urban planning can help reduce urban heat effects, improve air quality, strengthen climate resilience, and contribute to SDG 13 on climate action and SDG 15 on life on land.

Ecosystem Services for Green Recovery

The value of nature in supporting human well-being has long been recognized; however, the formal concept of ecosystem services has been systematically developed only in recent decades. Ecosystem services refer to the direct and indirect benefits that humans derive from natural systems, including provisioning, regulating, cultural, and supporting services. These include tangible resources such as food, timber, fibre, biomass, livestock, and fish, as well as regulating and supporting functions such as clean air, water regulation, climate regulation, soil formation, pollination, carbon sequestration, and biodiversity protection. A well-functioning ecosystem therefore plays a critical role in sustaining economic activity, supporting public health, maintaining food security, and providing the ecological foundations for a sustainable bioeconomy (Tallis & Kareiva, 2005).

Ecosystem services are directly relevant to the bioeconomy because biological resources cannot be used sustainably without maintaining the natural systems that regenerate them. Agriculture, forestry, fisheries, biomass production, and bio-based industries all depend on healthy ecosystems, soil fertility, water availability, biodiversity, and climate stability. From a circular bioeconomy perspective, ecosystem services should therefore be treated not only as environmental benefits but also as foundational assets that support long-term economic resilience and sustainable resource use. Figure 2 illustrates how natural capital and ecosystem functions generate ecosystem services that support green recovery and provide a foundation for sustainable bioeconomy development.

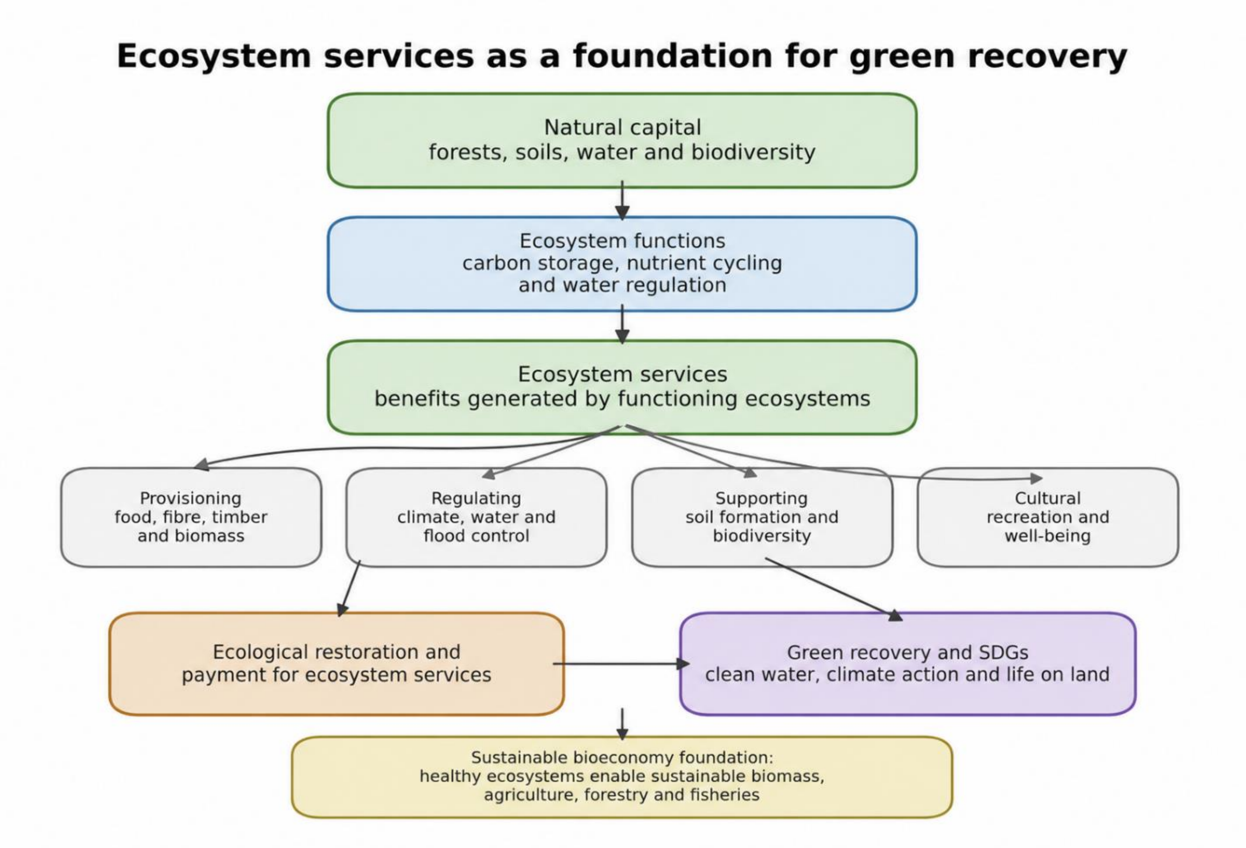

Figure 2: Ecosystem services as a foundation for green recovery

Note: The figure shows how natural capital generates ecosystem functions, which support ecosystem services and produce benefits for food security, public health, livelihoods, resilience, and green recovery. Ecosystem services form the ecological foundation of the bioeconomy because agriculture, forestry, fisheries, biomass production, and bio-based industries depend on healthy soils, water systems, biodiversity, and climate regulation.

Since 2000, China has invested more than USD 150 billion in ecological restoration, conservation, and environmental development programs. This investment reflects China's broader strategy of integrating ecological sustainability with economic development under the framework of ecological civilization. By promoting greater harmony between humans and nature, China aims to strengthen long-term ecological resilience while also supporting rural livelihoods and regional development. Evidence from China's natural-capital and ecosystem-restoration initiatives suggests that investments in ecosystem services can generate both ecological and socio-economic benefits, reinforcing their importance in sustainable development strategies (Natural Capital Project, 2012).

Two major national programs illustrate China's large-scale commitment to ecosystem restoration. The first is the Grain for Green Program (GTGP), also known as the Sloping Land Conversion Program, which focuses on converting environmentally fragile or degraded farmland into forest and grassland. The second is the Natural Forest Conservation Program (NFCP), which aims to protect natural forests through logging restrictions, afforestation, and ecological compensation mechanisms. Together, these programs are among the largest payment-for-ecosystem-services initiatives globally in terms of scale, financial investment, and potential ecological impact. They form a core component of China's forest conservation and ecological-restoration strategy, with combined planned investments exceeding 700 billion yuan (Liu et al., 2008).

These programs have contributed to reforestation, soil conservation, flood control, carbon sequestration, and improved vegetation cover, while also providing compensation and livelihood support to participating rural households. However, their long-term effectiveness depends on careful planning, adequate compensation, monitoring, and coordination between ecological protection and local development needs. This is important because ecosystem-restoration programs can create trade-offs if local communities lose access to land or resources without sufficient alternative livelihood support. Therefore, payment-for-ecosystem-services schemes should be designed to balance ecological objectives with social inclusion and rural welfare.

From a policy perspective, China's ecosystem-service approach is closely aligned with ecological civilization and with the broader transition toward a sustainable bioeconomy. Strengthening natural-capital accounting, ecological compensation mechanisms, biodiversity protection, and sustainable land-use planning can help ensure that economic development remains within ecological limits. These policy tools are also relevant to China's 14th Five-Year Plan priorities, which emphasize ecosystem protection, restoration, ecological security, and improved compensation mechanisms for environmental protection.

Further research is needed to identify, measure, and value ecosystem benefits more systematically in order to design effective pathways toward the Sustainable Development Goals (SDGs). Governments should strengthen access to essential ecosystem-based services, including clean drinking water, soil protection, biodiversity conservation, and sustainable land management, especially in rural and peri-urban regions. Policy frameworks should also minimize the environmental impacts of resource extraction by enforcing ecological limits and promoting responsible development practices.

A development model that integrates ecosystem preservation with inclusive economic growth can enhance both environmental sustainability and human well-being. For China's bioeconomy transition, ecosystem services are not simply a background condition; they are a core foundation for sustainable biomass production, rural resilience, climate mitigation, and long-term ecological security. This pathway contributes particularly to SDG 6 on clean water, SDG 12 on responsible production and consumption, SDG 13 on climate action, and SDG 15 on life on land.

Bioenergy, Renewable Energy, and Low-Carbon Transition

The continued global dependence on fossil fuels has generated significant environmental and economic externalities, including greenhouse gas emissions, climate instability, air pollution, and resource depletion. In response, China has increasingly prioritized the transition toward a low-carbon energy system as part of its long-term sustainable development strategy. This transition is closely linked to China's dual carbon goals of peaking carbon dioxide emissions before 2030 and achieving carbon neutrality before 2060. Within this broader strategy, bioenergy represents one component of a wider renewable-energy transition that also includes solar, wind, hydropower, hydrogen, and energy-efficiency improvements.

Bioenergy is directly relevant to the bioeconomy because it uses biological resources, such as agricultural residues, forestry residues, organic waste, biogas, biofuels, and biomass power, to generate energy and reduce dependence on fossil fuels. When developed sustainably, bioenergy can contribute to circular resource use by converting waste streams and residual biomass into useful energy. This can support rural development, waste management, and energy security. However, bioenergy is not automatically sustainable. Its environmental benefits depend on the source of biomass, land-use impacts, lifecycle emissions, and whether biomass extraction remains within ecological limits.

China's policy framework increasingly recognizes the role of bioenergy within the broader bioeconomy and renewable-energy transition. The 14th Five-Year Plan for Bioeconomy Development identifies bioenergy, biomaterials, biological breeding, and related industries as important areas for strengthening the national bioeconomy (National Development and Reform Commission, 2022). In parallel, China's renewable-energy and low-carbon policy frameworks emphasize the expansion of non-fossil energy, energy security, and the modernization of the energy system.

China's updated nationally determined contribution commits the country to increasing the share of non-fossil fuels in primary energy consumption to around 25 percent by 2030, lowering carbon dioxide emissions per unit of GDP by over 65 percent from the 2005 level, and bringing total installed wind and solar capacity to more than 1.2 billion kilowatts by 2030. These targets show that China's energy transition is not limited to bioenergy but forms part of a broader low-carbon transformation involving multiple renewable and non-fossil energy sources (UNFCCC, 2021).

Recent evidence highlights substantial progress in renewable-energy deployment. By the end of 2024, China's cumulative installed renewable-power capacity reached 1.889 billion kilowatts, accounting for 56 percent of the country's total installed power capacity. Solar power accounted for 887 million kilowatts, wind power for 521 million kilowatts, hydropower for 436 million kilowatts, and biomass power for 46 million kilowatts. Renewable-energy generation reached 3.46 trillion kilowatt-hours in 2024, accounting for about 35 percent of total electricity generation. These figures demonstrate the scale of China's renewable-energy expansion and the growing importance of non-fossil energy in its power system (State Council of the People's Republic of China, 2025).

Within this transition, bioenergy can play a complementary role rather than replacing solar and wind as the dominant renewable-energy sources. Biomass power, biogas, biofuel ethanol, biodiesel, and sustainable aviation fuel can contribute to energy diversification, particularly where they use agricultural residues, municipal organic waste, forestry residues, or other waste streams. This is especially relevant for rural areas, where biomass resources can support decentralized energy systems, circular agriculture, and local value creation. Nevertheless, bioenergy expansion requires careful regulation to avoid competition with food production, excessive land use, biodiversity loss, or increased emissions from unsustainable biomass harvesting.

The transition toward renewable energy and bio-based energy systems can contribute to environmental sustainability, economic restructuring, and green employment. Solar, wind, biomass power, and other non-fossil energy sectors support greenhouse-gas mitigation, energy security, and technological upgrading. In addition, renewable-energy infrastructure and bioenergy value chains can generate employment opportunities in rural biomass collection, waste management, biorefining, energy infrastructure, and green technology sectors.

However, China remains one of the world's largest consumers of coal, and the pace and effectiveness of the energy transition remain critical policy concerns. Sustained efforts are required to accelerate coal phase-down, strengthen grid integration of renewable energy, improve energy storage, and ensure that bioenergy development is based on sustainable biomass sourcing. From a bioeconomy perspective, the key policy challenge is not simply to expand renewable energy, but to ensure that bioenergy and other non-fossil energy systems contribute to circularity, carbon-emission reduction, rural development, and long-term ecological sustainability.

Bio-based Materials and Circular Industrial Transformation

Global production and consumption patterns have expanded significantly over recent decades, increasing pressure on natural resources, ecosystems, and waste-management systems. Despite efficiency improvements, industrial production remains heavily dependent on material-intensive and fossil-based inputs. The International Resource Panel has shown that global resource use has continued to rise rapidly, creating major environmental pressures through greenhouse-gas emissions, biodiversity loss, pollution, and waste generation (United Nations Environment Programme, 2024). In this context, the transition toward resource-efficient, circular, and bio-based material systems has become an important pathway for sustainable industrial transformation.

Bio-based materials refer to materials derived partly or wholly from renewable biological resources, including agricultural residues, forestry biomass, algae, microorganisms, and other organic feedstocks. These materials include bioplastics, biodegradable packaging, bio-based chemicals, bio-textiles, bamboo and wood-based products, bio-composites, and cellulose-based materials. Within a circular bioeconomy, such materials can reduce dependence on fossil-based inputs, improve material efficiency, and create value from biomass and waste streams. However, their sustainability depends on feedstock sourcing, land-use impacts, lifecycle emissions, biodegradability, recyclability, and the governance systems used to regulate production and disposal.

For China, bio-based materials are increasingly relevant to the national transition toward green industrial development. China's 14th Five-Year Plan for Bioeconomy Development identifies the bioeconomy as a strategic area and highlights the importance of bio-based industries, including biomaterials, bioenergy, biological breeding, and biotechnology-based innovation (National Development and Reform Commission, 2022). This policy direction reflects the broader objective of reducing dependence on fossil-based production systems while promoting high-quality industrial upgrading, innovation, and environmental sustainability.

Bio-based materials are also closely connected to China's efforts to reduce plastic pollution. During the 14th Five-Year Plan period, China introduced policy measures to control plastic pollution and reduce the unreasonable use of disposable plastics in key sectors such as retail, e-commerce, and express delivery. These measures promote alternatives to conventional plastics, including bamboo, wood, paper, and degradable plastics, while also encouraging research and development in degradable-plastic technologies. Such policies create opportunities for bio-based materials to contribute to responsible production and consumption, especially when they are integrated with recycling systems, waste reduction, and circular design (State Council of the People's Republic of China, 2021).

The development of bio-based materials can also support rural and regional economic development. Agricultural residues, forestry by-products, and organic waste can be converted into higher-value materials through biorefining, industrial biotechnology, and circular manufacturing systems. This can create new value chains linking agriculture, forestry, manufacturing, packaging, textiles, construction, and waste-management sectors. In this way, bio-based materials can contribute not only to environmental objectives but also to rural revitalization, employment creation, and industrial diversification.

At the same time, bio-based materials should not be treated as automatically sustainable substitutes for fossil-based materials. If biomass demand expands without adequate safeguards, it may increase pressure on land, water, forests, and biodiversity. Some biodegradable materials may also fail to deliver environmental benefits if appropriate composting, recycling, or waste-management infrastructure is absent. Therefore, China's bio-based material transition requires lifecycle assessment, clear product standards, sustainable biomass sourcing, and stronger coordination between industrial policy, environmental regulation, and waste-management systems.

From a sustainable-development perspective, bio-based materials can contribute to China's circular bioeconomy by reducing fossil-resource dependence, improving material efficiency, supporting innovation, and creating new green industrial value chains. This pathway is particularly relevant to SDG 9 on industry, innovation and infrastructure, SDG 12 on responsible consumption and production, and SDG 13 on climate action. However, these benefits depend on whether bio-based material production is embedded within circular-economy principles, ecological safeguards, and effective governance mechanisms.

Bio-Based and Eco-Integrated Cities in the Bioeconomy

Urban systems play a pivotal role in shaping the transition toward a sustainable bioeconomy because they concentrate population, economic activity, infrastructure, consumption, waste generation, and resource demand. In this context, cities should not be viewed only as consumers of biological resources, but also as potential hubs for circular resource management, green infrastructure, urban agriculture, organic-waste recovery, wastewater reuse, and bio-based innovation. A bio-based urban system can therefore contribute to sustainable development when it connects biological resources, infrastructure, research institutions, industries, communities, and governance systems in ways that generate environmental and socio-economic value.

Technological advancements have also transformed urban mobility patterns and living standards, contributing to the emergence of more sustainable and digitally integrated urban systems. In China, the expansion of electric and low-emission mobility has supported efforts to reduce urban air pollution and improve environmental quality, thereby contributing to the development of low-carbon cities (Acuto et al., 2020; Li et al., 2019). However, clean mobility should be understood as part of the broader low-carbon urban transition rather than as a bioeconomy pathway by itself. It becomes relevant to the bioeconomy when it is linked with renewable energy, bioenergy, circular resource systems, and green urban planning.

Bio-based urban development is most directly connected to the bioeconomy through the integration of urban agriculture, peri-urban forestry, green infrastructure, organic-waste recycling, composting, bioenergy generation from municipal waste, and the use of bio-based materials in construction and urban design. Successful regional circular bioeconomy systems integrate local resources with innovation actors to improve resilience and sustainability (Morone et al., 2026). Such systems can reduce waste, create local value chains, improve air quality, support biodiversity, and strengthen rural-urban linkages.

A frequently cited example of eco-integrated urban development in China is the proposed "Forest City" in Liuzhou, designed by Stefano Boeri Architetti. The project has been presented as a model that integrates vegetation, renewable energy, and urban planning into a new urban district. It was planned to accommodate around 30,000 residents and incorporate extensive tree and plant cover across buildings and infrastructure. The project was also projected to absorb approximately 10,000 tonnes of carbon dioxide and 57 tonnes of pollutants annually. However, this example should be treated cautiously as a proposed or planned model of ecological urbanism rather than as completed evidence of a fully functioning bio-based city (Lant, 2017).

International initiatives such as The Line in Saudi Arabia may be mentioned only as comparative examples of experimentation with low-carbon urban design, but they should not be treated as core evidence for China's bioeconomy because they are outside the Chinese policy context and are not specifically bio-based urban systems. For the purposes of this paper, the focus remains on how China can integrate green infrastructure, circular resource management, bio-based materials, urban agriculture, and rural-urban linkages into sustainable urban development.

Bio-based and eco-integrated cities can contribute to environmental transition by embedding ecological functions directly into urban infrastructure. Their effectiveness, however, depends on systemic integration. Urban agriculture and peri-urban forestry can enhance local food production, improve ecosystem services, reduce supply-chain emissions, and support biodiversity. Organic-waste recycling and bioenergy systems can convert urban waste streams into useful inputs, while green infrastructure can reduce urban heat effects, improve air quality, and strengthen resilience to climate risks.

Furthermore, the development of rural-urban linkages remains essential for achieving balanced regional development within the bioeconomy framework. Strengthening rural economies through training, technological support, circular agriculture, biomass value chains, and green employment opportunities can reduce rural-urban disparities while supporting sustainable resource management. In the case of China, such integrated development strategies can contribute not only to environmental sustainability but also to inclusive economic growth, ecological civilization, and long-term structural transformation.

Challenges and Trade-Offs in China's Bioeconomy Transition

Despite substantial progress, China's bioeconomy transition faces several structural challenges. First, large-scale biomass utilization may create land-use competition between food production, bioenergy generation, biomaterials, and ecological conservation. If not carefully regulated, this may increase pressure on land, water, forests, and biodiversity. Second, the expansion of forest-based industries may create risks for ecosystem stability if harvesting practices exceed ecological carrying capacity or if forest carbon stocks are not adequately protected.

Third, bioenergy and bio-based material production require careful lifecycle assessment. Bio-based products and biomass energy are not automatically low-carbon or environmentally sustainable. Their actual benefits depend on feedstock sourcing, production methods, transport requirements, land-use impacts, waste-management systems, and end-of-life treatment. Without circular design and effective environmental regulation, bio-based transitions may reproduce some of the same unsustainable patterns associated with fossil-based production systems.

Fourth, urban bioeconomy models require substantial investment, institutional coordination, and technological capacity. Bio-based cities, circular waste systems, urban agriculture, and green infrastructure depend on coordination across local governments, environmental agencies, planning authorities, private firms, research institutions, and communities. Weak coordination may limit the effectiveness of these initiatives, particularly across regions with different levels of fiscal capacity and technological readiness.

Fifth, social inclusion remains an important challenge. Bioeconomy policies can generate new green employment opportunities, rural value chains, and innovation-led growth, but they may also create distributional pressures if local communities bear the costs of land-use change, resource restrictions, or ecological restoration without adequate compensation. Therefore, the bioeconomy transition must be supported by inclusive governance, fair compensation mechanisms, public participation, and policies that protect rural livelihoods.

Institutional and governance-related barriers may further affect implementation. Effective coordination between environmental agencies, industrial sectors, agricultural authorities, urban planners, and regional governments remains essential for long-term policy success. Therefore, the effectiveness of China's bioeconomy transition depends not only on technological innovation but also on governance efficiency, regulatory consistency, lifecycle monitoring, ecological safeguards, and sustained financial support (Camia et al., 2021; Oláh et al., 2023; Pfau et al., 2014; Uwe et al., 2021).

Comparative Assessment of Bioeconomic Pathways

A comparative assessment suggests that different bioeconomic pathways contribute to China's sustainable development in different ways and over different time horizons. Sustainable agriculture and food-system transformation offer strong short- to medium-term potential because they directly affect food security, rural livelihoods, resource efficiency, and agricultural emissions. Ecological agriculture, circular nutrient management, agricultural-waste recycling, and biological breeding can therefore make immediate contributions to China's bioeconomy transition and to SDG 2, SDG 12, and SDG 13 (Wu, Riaz, et al., 2022; Wu, Xie, et al., 2022; Yang et al., 2022).

Bioenergy and renewable-energy integration also contribute to China's low-carbon transition, but they should be conceptually distinguished. Solar and wind energy are central to China's renewable-energy expansion, while bioenergy is specifically linked to the bioeconomy through biomass, organic waste, agricultural residues, forestry residues, biogas, and biofuels. Bioenergy can complement other renewable sources by supporting rural energy systems, waste valorisation, and circular biomass use. However, its sustainability depends on feedstock availability, lifecycle emissions, and safeguards against land-use and biodiversity pressures.

Forestry and ecosystem restoration generate significant long-term ecological and climate benefits through carbon sequestration, biodiversity conservation, soil protection, water regulation, and environmental resilience. These pathways are central to China's ecological civilization agenda and to SDG 15. However, their economic and environmental benefits often require longer time horizons and careful governance to ensure that forest-based biomass use does not undermine ecosystem stability (Camia et al., 2021; Liu et al., 2008; Wolfslehner et al., 2016).

Bio-based materials and circular industrial transformation represent important pathways for reducing dependence on fossil-based inputs and improving material efficiency. Their contribution is especially relevant to industrial upgrading, packaging, textiles, construction, biotechnology, and waste reduction. However, these benefits depend on sustainable sourcing, lifecycle assessment, product standards, recycling systems, and clear regulation of biodegradable and bio-based products.

Bio-based and eco-integrated cities represent high-potential models for sustainable urban transformation, particularly through urban agriculture, green infrastructure, organic-waste recovery, bioenergy systems, and rural-urban circular resource flows. Yet their implementation requires substantial capital investment, technological infrastructure, governance coordination, and long-term planning, which may limit rapid scalability across regions (Acuto et al., 2020; Li et al., 2019).

Overall, sustainable agriculture, circular biomass use, bio-based materials, and ecosystem restoration appear most directly connected to China's bioeconomy transition, while renewable energy and clean mobility provide important complementary support within the broader low-carbon development agenda. From a policy-prioritization perspective, China should pursue a balanced strategy: strengthening agriculture and bio-based industrial innovation in the short to medium term, while continuing long-term investment in forestry, ecosystem services, and eco-integrated urban systems. This balanced approach would allow the bioeconomy to contribute to resource efficiency, carbon-emission reduction, rural development, biodiversity protection, and the Sustainable Development Goals. Figure 3 summarises the main bioeconomic pathways identified in this paper and shows how they contribute to China's sustainable development objectives and selected SDGs.

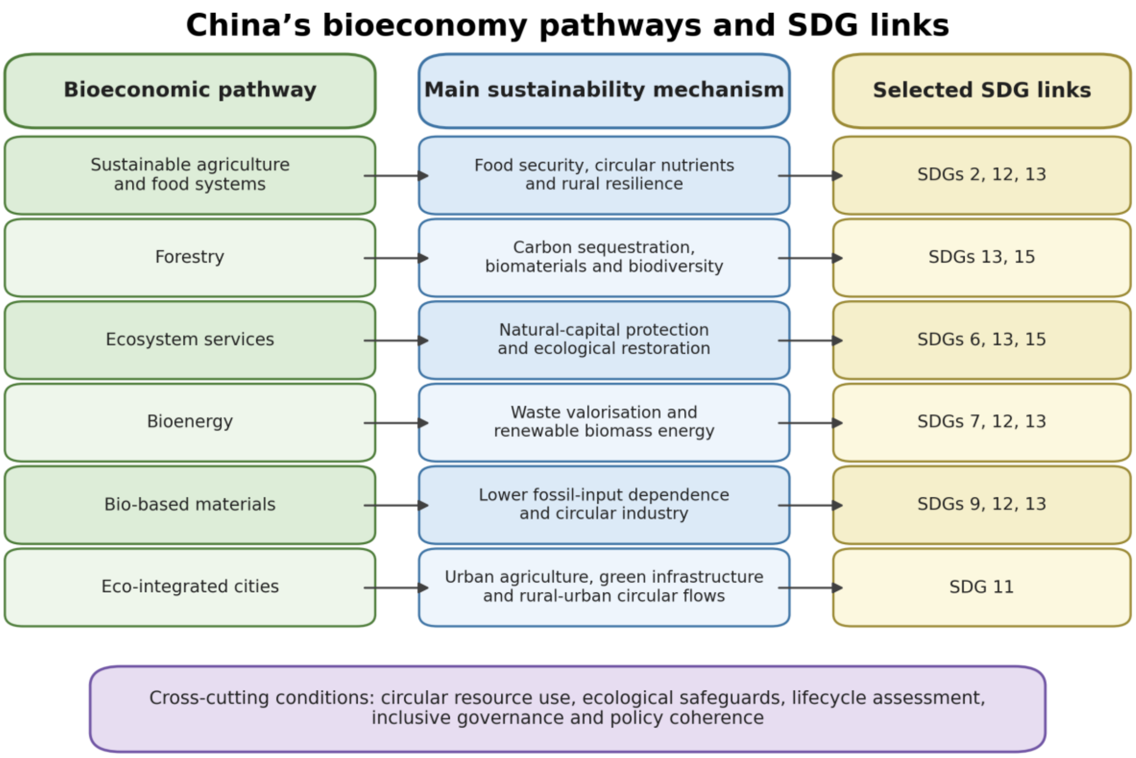

Figure 3: China's bioeconomy pathways and SDG links

Note: The figure summarizes the main bioeconomic pathways examined in the paper and links them to key sustainability mechanisms and selected Sustainable Development Goals. The pathways are conceptually distinct but mutually reinforcing. Sustainable agriculture, forestry, ecosystem services, bioenergy, bio-based materials, and eco-integrated cities contribute to sustainable development only when supported by coherent policy, circularity principles, and environmental safeguards.

Table 1: China's Bioeconomy and Sustainability Policy Framework

Policy / Plan	Main relevance to the bioeconomy
National Medium- and Long-Term Program for Science and Technology Development (2006–2020)	Supports science, technology, and innovation capacity relevant to biotechnology, agriculture, health, and industrial upgrading.
Policies to Promote Rapid Development of the Biological Industry (2009)	Provides early policy support for the development of biological industries and biotechnology-based economic activities.
12th Five-Year Plan (2011–2015) on Agricultural Science and Technology Development	Promotes agricultural science, technological modernization, and productivity improvements relevant to sustainable agricultural development.
National Modern Agriculture Development Plan	Supports agricultural modernization, food security, and productivity enhancement within China's rural development strategy.
National Sustainable Agricultural Development Plan (2015–2030)	Provides a long-term framework for sustainable agriculture, resource conservation, reduced chemical input intensity, and green rural development.
13th Five-Year Plan for Economic and Social Development (2016–2020)	Establishes broader national priorities for innovation, green development, ecological protection, and industrial transformation.
13th Five-Year Plan for Environmental Protection	Supports pollution control, environmental governance, and ecological protection relevant to sustainable resource use.
13th Five-Year Plan for Bioindustry Development	Promotes biological industries, biotechnology, biomanufacturing, and related innovation-based sectors.
13th Five-Year Plan for National Strategic Emerging Industries	Supports strategic emerging industries, including biotechnology, advanced materials, and green technologies.
13th Five-Year Plan for Renewable Energy Development	Promotes renewable energy expansion and supports the broader low-carbon transition.
14th Five-Year National Agricultural Green Development Plan (2021–2025)	Strengthens green agricultural development, resource conservation, agricultural waste recycling, reduced fertilizer and pesticide intensity, and rural environmental protection.
14th Five-Year Plan for Renewable Energy Development (2021–2025)	Supports renewable energy expansion, energy-system modernization, and the transition toward non-fossil energy sources.
14th Five-Year Plan for Bioeconomy Development (2021–2025)	Provides China's most direct national policy framework for the bioeconomy, covering biotechnology, biological breeding, biomedicine, bio-based materials, bioenergy, and bio-based industries.
14th Five-Year Action Plan for Plastic Pollution Control	Promotes alternatives to conventional plastics, including bamboo, wood, paper, and degradable plastics, and supports the development of circular material systems.

Policy / Plan	Main relevance to the bioeconomy
14th Five-Year Plan for Ecological and Environmental Protection	Strengthens ecological restoration, pollution control, biodiversity protection, and environmental governance.

Source: Compiled by the authors from China's national policy documents and official policy summaries, including the National Development and Reform Commission, State Council, Ministry of Agriculture and Rural Affairs, and Ministry of Ecology and Environment.

CONCLUSIONS

This study examined strategic pathways through which the bioeconomy can support China's transition toward a greener and more sustainable development model. Using a conceptual and policy-oriented review approach, the paper linked China's bioeconomic pathways to the Circular Economy, Ecological Modernization Theory, and the Sustainable Development Goals framework. The analysis shows that the bioeconomy can contribute to sustainable development when biological resources, technological innovation, circular resource use, and environmental governance are integrated within a coherent policy framework.

Agriculture and food systems remain central to China's bioeconomy transition. Sustainable agriculture, ecological farming, biological breeding, circular nutrient management, and agricultural-waste valorisation can improve food-system resilience while reducing environmental pressures from intensive production. These pathways are particularly relevant to food security, rural revitalization, responsible production, and climate action. However, continued policy strengthening is required to reduce excessive reliance on chemical fertilizers and pesticides, improve waste recycling, and promote climate-resilient farming systems.

Forestry and ecosystem services also represent core foundations of a sustainable bioeconomy. Forests provide biomass, bio-based materials, carbon sequestration, biodiversity protection, and climate-regulation benefits. At the same time, ecosystem services support the natural resource base on which agriculture, forestry, fisheries, and bio-based industries depend. China's ecological restoration programs, including large-scale forest conservation and land-restoration initiatives, demonstrate the importance of linking ecological protection with rural development and national sustainability objectives. Nevertheless, forest-based and ecosystem-based bioeconomy pathways must remain within ecological limits to avoid biodiversity loss, land degradation, and unsustainable biomass extraction.

The analysis also highlights the importance of distinguishing bioenergy from the broader renewable-energy transition. Solar and wind energy are central to China's low-carbon development strategy, while bioenergy is specifically linked to the bioeconomy through biomass, agricultural residues, forestry residues, organic waste, biogas, and biofuels. Bioenergy can contribute to circular resource use and rural energy systems, but its sustainability depends on feedstock sourcing, lifecycle emissions, and safeguards against land-use competition.

Bio-based materials and circular industrial transformation provide another important pathway for reducing dependence on fossil-based inputs. Biomaterials, bio-based chemicals, biodegradable packaging, wood-based products, and cellulose-based materials can support industrial upgrading and responsible consumption when they are embedded within circular-economy principles. However, bio-based materials should not be treated as automatically sustainable. Their environmental benefits depend on sustainable biomass sourcing, lifecycle assessment, product standards, recycling systems, and effective waste-management infrastructure.

Bio-based and eco-integrated cities can further support China's bioeconomy transition by connecting urban agriculture, green infrastructure, organic-waste recovery, bioenergy from municipal waste, bio-based materials, and rural-urban circular resource flows. Proposed models such as Liuzhou Forest City illustrate how ecological urbanism can be incorporated into urban planning, although such examples should be treated as planned or experimental models rather than conclusive evidence of fully realized bio-based cities. The effectiveness of bio-based urban development depends on economic feasibility, governance capacity, social inclusion, and integration with broader circular resource systems.

Overall, China's transition toward a modern bioeconomy represents a strategic pathway for advancing sustainable development objectives. The identified pathways contribute to multiple Sustainable Development Goals. Sustainable agriculture supports SDG 2 on zero hunger, SDG 12 on responsible consumption and production, and SDG 13 on climate action. Renewable energy and bioenergy contribute to SDG 7 on affordable and clean energy and SDG 13 on climate action. Bio-based materials and industrial innovation support SDG 9 on industry, innovation and infrastructure and SDG 12 on responsible production and consumption. Bio-based urban development contributes to SDG 11 on sustainable cities and communities, while forestry and ecosystem restoration support SDG 15 on life on land.

However, the bioeconomy is not inherently sustainable. Without intentional policy design, circularity principles, resource-efficiency measures, biodiversity safeguards, lifecycle assessment, and inclusive governance systems, bio-based transitions may simply replace fossil dependency with new ecological and social pressures. Therefore, the success of China's bioeconomy transition depends not only on technological innovation, but also on regulatory consistency, institutional coordination, sustainable financing, ecological protection, and public participation.

Future research should focus on developing stronger indicators for assessing China's bioeconomy performance, measuring lifecycle impacts of bio-based products, evaluating trade-offs between biomass use and ecosystem conservation, and examining how bioeconomy policies affect rural livelihoods and regional inequality. A sustainable bioeconomy should therefore be understood as a conditional development pathway: it can support China's green transformation and SDG implementation, but only when embedded within circular resource governance, ecological safeguards, and inclusive development strategies.

Data Availability Statement

No new datasets were generated or analysed during the current study. The analysis is based on publicly available academic literature, policy documents, and secondary sources cited in the manuscript.

Conflict of Interest

The authors declare that they have no conflicts of interest regarding the publication of this paper.

Authors' Contributions

All authors contributed equally to the conception, design, analysis, drafting, and revision of this manuscript.

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