

India's Bioeconomy

PIONEERING GROWTH THROUGH INNOVATION AND SUSTAINABILITY



The world is at the cusp of a new industrial revolution driven by bio-innovation. Among emerging economies, India's Bioeconomy represents a remarkable journey of innovation, growth, and increasing global influence. Over the past decade, India's Bioeconomy has grown significantly from \$10 billion in 2014 to \$151 billion by the end of 2023. With the launch of ambitious **BioE3 (Biotechnology for Economy, Environment and Employment)**, India is expected to reach \$300 billion by 2030, marking a crucial step in economic transformation and positioning India as a global biotech leader.

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I. What does the term Bioeconomy mean?

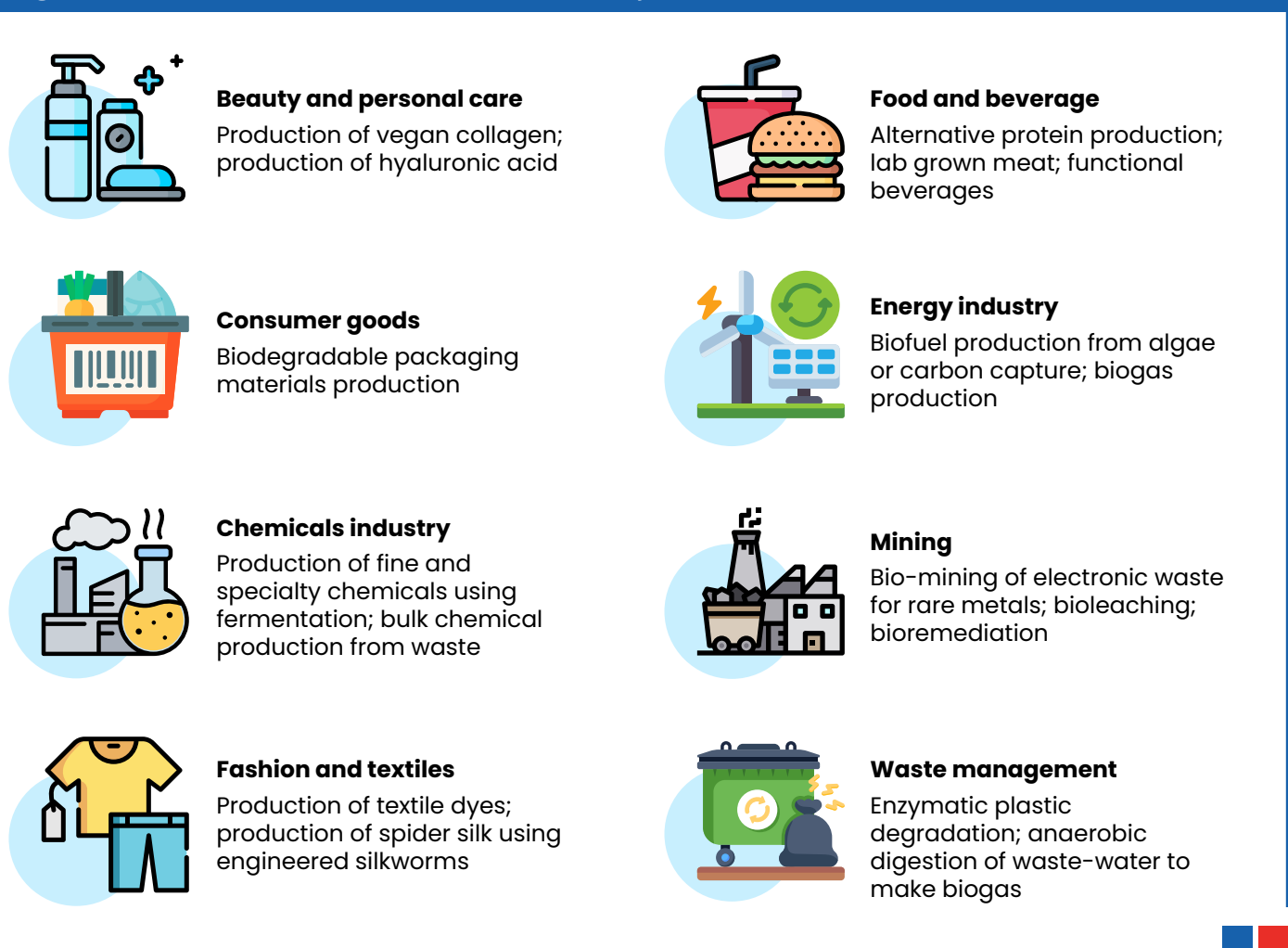
As per Food and Agriculture Organization (FAO), Bioeconomy is defined as **production, utilization, conservation, and regeneration of biological resources, including related knowledge, science, technology, and innovation, to provide sustainable solutions** (information, products, processes and services) within and across all economic sectors and enable transformation to sustainable economy.

I.1. What are the different subsectors of Bioeconomy?

Bioeconomy spans several key subsectors, each contributing significantly to national growth through biotechnology.

- ▶ **BioIndustrial:** This emerging sector deals with **biobased chemicals and products created using enzymes, biosynthetic processes, and recombinant DNA technology**. It includes bioplastics, biogas, and enzymatic applications across industries.
 - ▶ It focuses on areas like **cancer immunotherapy, gene editing, precision medicine**, and biologics, encompassing MedTech and diagnostics.
- ▶ **BioAgri:** Focusing on agricultural biotechnology, it covers **genetically modified crops and animals, precision agriculture, and bio-based products**.
 - ▶ E.g., **Bt Cotton** highlights biotech's role in boosting agricultural yields and sustainability.
- ▶ **BioResearch and BioIT (BioServices):** It involves **contract research, clinical trials, biotech software and databases, specialized equipment**, and bioscience education services.
- ▶ **BioPharma and BioMedical:** It includes **development of pharmaceuticals, medical devices, diagnostics, and lab-grown organoids**.

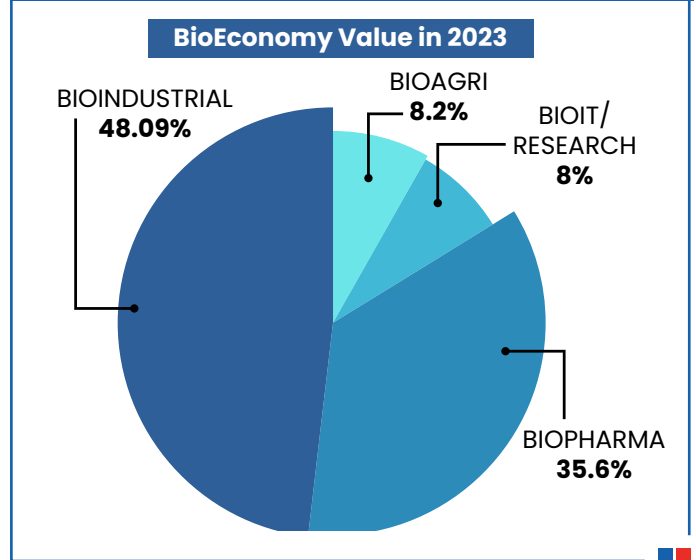
Figure I.1. Other Opportunities in Bioeconomy



Box 1.1. Status of India's Bioeconomy (As per India BioEconomy Report 2024)

- **Share in GDP:** Reached ~\$151 billion, accounting for **4.25% of India's Gross Domestic Product (GDP)** of \$3.55 trillion in 2023.
- **Growth over the years:** India's national BioEconomy has nearly **doubled in four years**.
 - From 2013 to 2018, the bioeconomy experienced an exponential surge, reaching \$55 billion – a **400% growth**.
- **Global rank:** India is among the world's **Top 5 BioEconomies**.
- **Employment:** Bio-economy sector employs over 3.3 million people.
- **Sector-specific indicators:**
 - **Vaccine manufacturing:** According to the WHO, the Serum Institute of India's share of the global vaccine market, excluding COVID-19 vaccines, increased from 19% in 2021 to 24% in 2023.
 - **Biofuels:** As of the end of 2023, India was the 3rd largest producer of blended ethanol, with production nearly **tripling over the past five years**.
 - **Startups:** Between 2021 and 2023, the cumulative number of biotech startups saw a **59% growth**.
 - » Leading states in biotech are Maharashtra, Karnataka, Telangana, Delhi, and Uttar Pradesh, which together host over 50% of the country's startups.

Figure 1.2. Subsector Contributions to India's BioEconomy



2. What makes Bioeconomy essential in India's growth journey?

Over the past decade, India's Bioeconomy has emerged as a significant force, driven by key sectors such as vaccines, bio-therapeutics, bioethanol, etc. The sector's progress underscores its vital role in promoting sustainable development and enhancing resilience in key areas like healthcare, agriculture etc.

- **Economic Growth:** Bioeconomy can contribute to India's economic growth by **creating new industries, businesses, and job opportunities** in sectors like agriculture, pharmaceutical, and diversify India's economic base.
 - By 2050, the global BioEconomy is expected to expand significantly, contributing \$30 trillion to the world economy (from growing \$4 trillion), representing nearly **12% of the projected global GDP**.
- **Food Security:** It can **enhance India's food security by improving agricultural productivity** and soil health, developing nutritious, climate-resilient crops, through innovative biotechnologies farmers and biological alternatives like Biofertilizers.
 - E.g. GM technology has increased crop yields by 21% and **Golden rice can aid in combating Vitamin-A deficiency**.
- **Healthcare:** Advancements in bioeconomy can lead to **development of new drugs, vaccines, etc.**, and enhance accessibility and affordability of healthcare, thus improving health outcomes. For example-
 - **Serum Institute of India**, launched India's first indigenously developed Quadrivalent Human Papillomavirus (qHPV) vaccine, CERVAVAC, marking a significant milestone in women's well-being.
 - India's **first gene therapy clinical trial for Hemophilia A** was approved advancing the treatment of genetic blood disorders.
- **Employment opportunities:** Bioeconomy can drive **job creation in India especially in sectors like biopharmaceuticals, bioenergy** etc., and foster entrepreneurship in tier-2 and 3 cities through development of bio-manufacturing hubs.
 - BioEconomy is projected to **create 35 million jobs by 2030**.
- **Bio startups:** India's bioeconomy will play an important role in fostering a vibrant startup ecosystem.
 - The number of biotech startups in India is expected to surge from 8,531 in 2023 to **35,460 by 2030**.
- **Exports:** India is one of the **biggest suppliers of low-cost drugs and vaccines** in the world, further growth in biologics and bio-similar industry can boost growth in India's exports.

- ▶ E.g., Indian manufacturers supplied **25% of total vaccine volumes** purchased by World Health Organisation (WHO).
- ▶ **Environmental benefits:**
 - ▶ **Promoting Circular economy:** Bioeconomy focuses on minimizing waste and **maximizing resource efficiency** through closed loop production and consumption.
 - » For example, **agricultural waste can be converted into biogas** (anaerobic digestion), with remnants used as a nutrient-rich fertilizer, reducing waste, and promoting reuse.
 - ▶ **Lowering environmental pollution:** Bioeconomy products, such as biofertilizers, biopesticides etc. reduce harmful chemicals in the environment and improve ecosystem health.
 - ▶ **Conservation of biodiversity:** Bioeconomy can harness traditional and Indigenous knowledge and use latest advances in biosciences and innovation, including DNA sequencing, to enhance biodiversity knowledge and conservation.
 - » E.g., **Environmental DNA**, was used by the World Wildlife Fund (WWF) in Peru in 2018 for biodiversity discovery and conservation.
- ▶ **Eco-restoration:** Bioremediation can be used to restore polluted soils, wetlands and freshwater ecosystems.
 - » E.g., **TERI's Oilzapper technology** uses naturally occurring microorganisms to transform hydrocarbon contaminants in soil to non-toxic compounds.
- ▶ **Biologizing industries:** Biological resources can replace petrochemical-based energy sources and chemicals with biologically derived alternatives.
 - » E.g., Modifying lignin in trees using CRISPR could provide eco-friendly alternatives to producing industrial chemicals, traditionally made from petroleum.
- ▶ **Climate action:** Bioeconomy can **reduce India's carbon footprint** and help meet climate goals like 45% reduction in emission intensity by 2030 and achieving net zero by 2070.

Box 2.1: How Bioeconomy can assist in combating climate change?

The circular bioeconomy presents a sustainable solution for climate mitigation and adaptation-

- ▶ **Carbon sequestration:** Bio-based materials derived from biomass like wood, agricultural residues etc. can **capture and store atmospheric carbon, reducing greenhouse gas (GHG)** levels.
 - ▶ For example, using engineered wood products like CLT (cross-laminated timber) in large-scale construction projects can create a **carbon sink and reduce reliance on carbon-intensive materials** like concrete and steel.
- ▶ **Renewable energy:** Bioeconomy is key to achieving India's E2o target (blending 20% ethanol with petrol (E2o) by 2025) which will cut GHG emissions.
 - ▶ Biofuels and **biomass are renewable, carbon-neutral energy sources**, as they are derived from plants and waste that can be replenished.
- ▶ **Climate resilient agriculture:** Bioeconomy promotes **innovations like climate-resilient crops**, soil amendment, and aid food systems adaptation to changing climate condition, ensuring food security.
 - ▶ For example, **biochar derived from agricultural waste** can be used as a soil amendment to improve fertility and sequester carbon in agricultural lands.

3. What are the various initiatives that have been taken to boost India's Bioeconomy?

India has embarked on a series of transformative policy reforms with focus on biotechnology, sustainable agriculture, biofuels, healthcare, and environmental sustainability to boost its Bioeconomy. Some of major steps are as follows:

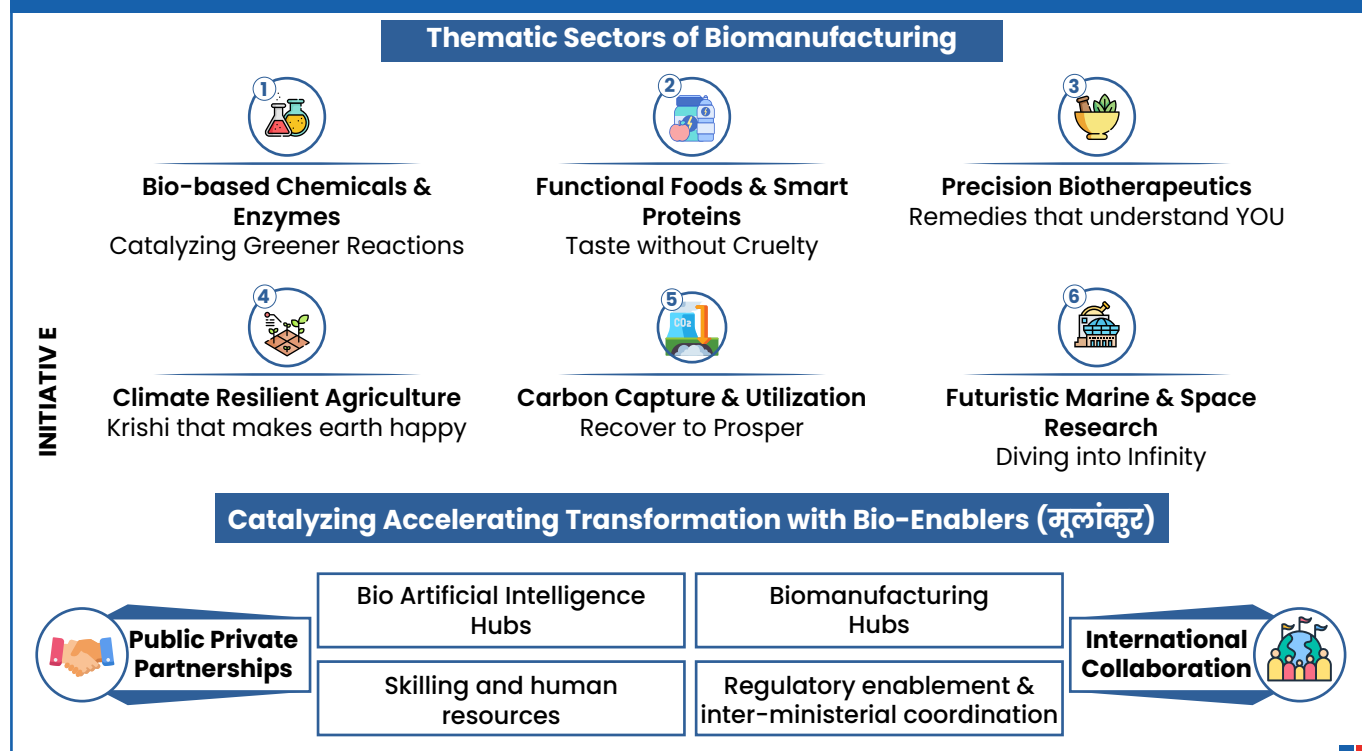
Policy making

- ▶ **BioE3 (Biotechnology for Economy, Environment and Employment) Policy:** Implemented by Department of Biotechnology (DBT), it sets forth a framework for 'Fostering High Performance Biomanufacturing'.

Box 3.1: BioE3 Policy: A Catalyst for India's Biotech Revolution

- **Goal of the Policy:** To fast-track innovation-to-technology in a sustainable manner by **weaving together fragmented activities** under the umbrella of biomanufacturing and to incentivize concrete options to build a sustainable future.
- It will have focused mission in six thematic sectors. (refer Figure 3.1)

Figure 3.1. Thematic Sectors of BioE3



- The research and translational activities under these verticals will be catalyzed by **Bio-Enablers:**
 - **Biomanufacturing Hubs:** To provide common usage of pilot and pre-commercial manufacturing facilities for researchers, startups and SMEs to support early-stage manufacturing.
 - **Bio-Artificial Intelligence (AI) Hubs:** To bring together experts from both biological and computational disciplines to address complex challenges and advance our understanding of living systems.

➤ Sector specific Policy Initiatives:

- **National Mission on Bioeconomy, 2016:** Launched by the Institute of Bio-resources and Sustainable Development (under Ministry of Science and Technology) to boost **rural economy by utilising bio-resources.**
- **Draft National Biotechnology Development Strategy (2020-2025):** To make India globally competitive in biotechnology research, innovation, translation, entrepreneurship and industrial growth and be a USD 150 billion Bioeconomy by 2025.
- **Other policies:** National Medical Device Policy, 2023; National Policy on Biofuels, 2018 etc.

Schemes and initiatives

- **For promoting innovation:** Biotechnology Research Innovation and Entrepreneurship Development (**Bio- RIDE**) Scheme; **Biotech Science Clusters** etc.
- **Global Biofuel Alliance:** Led by India, Brazil, and United States, it presents an opportunity for India to reduce costly oil imports, **boost domestic biofuel production**, and enhance economic stability.
- **Sector specific schemes:** National Biopharma Mission; Production Linked Incentive (PLI) Scheme for Pharmaceuticals; National Green Hydrogen Mission; PM-JIVAN Yojna, SATAT, and GOBARDhan scheme etc.

Table 3.1: Other key Initiatives in Healthcare Sector

Indian SARS-CoV-2 Genomics Consortium (INSACOG)	<ul style="list-style-type: none"> ➤ A joint initiative of Union Health Ministry of Health and DBT with Council of Scientific & Industrial Research (CSIR) and the Indian Council of Medical Research (ICMR). ➤ Launched in 2020, it is a multi-laboratory, multi-agency, Pan-India network to monitor genomic variations in SARS-CoV-2.
Establishment National Biological Data Centre (IBDC) at Faridabad	<ul style="list-style-type: none"> ➤ India's first repository for life science data, supported by DBT. ➤ Mandate: To archive all life science data generated from publicly funded research in India.
Data-Driven Research to Eradicate TB (DarezeraD TB) program	<ul style="list-style-type: none"> ➤ Umbrella TB program of DBT comprising key initiatives like Indian Tuberculosis Genomic Surveillance Consortium, and developing an evidence-based regimen for treating extra-pulmonary TB.

Governance and Regulatory Initiatives

- **Biotechnology Research and Innovation Council (BRIC):** It aims to streamline governance and amplify the impact of biotech research across the nation. It has established various industry focused schemes like-
 - **Biotechnology Ignition Grant Scheme**, an early stage biotech funding programme in India.
 - **Bioincubators Nurturing Entrepreneurship for Scaling Technologies (BioNEST)** to create globally competent bioincubation facilities across country.
 - **Small Business Innovation Research Initiative (SBIRI) and Biotechnology Industry Partnership Program (BIPP):** To enhance R&D capabilities for biotechnological product and technology development.
- **Biological Research Regulatory Approval Portal (BioRRAP):** It **simplifies the approval process for biological research**.
- **Intellectual Property (IP) Guidelines, 2023:** DBT introduced new IP guidelines to **improve commercialization of public-funded research**.
- **Guidelines for Genetically Engineered Insects, 2023:** It ensures stringent biosafety measures while maximizing the benefits of genetic engineering.

Regional initiatives

- **Uttar Pradesh Pharmaceutical and Medical Devices Industry Policy 2023:** Aims to streamline regulatory processes and attract investments
- **Tamil Nadu's Ethanol Blending Policy:** Aligned with National Biofuels Policy's vision of achieving 20% ethanol blending by 2025, Tamil Nadu aims to leverage its agricultural abundance to bolster ethanol production.

Table 3.2: Global Bioeconomy Policy Frameworks

European Union	<ul style="list-style-type: none"> ➤ European Bioeconomy Strategy (first released in 2012 and updated in 2017 and 2018) aims to promote sustainable growth, enhance resource efficiency, drive innovation, support bio-based industries, and ensure a balanced policy framework. ➤ European Green Deal (EGD), launched in 2019, targets a resource-efficient economy with net-zero greenhouse gas emissions by 2050, integrating initiatives across Research and Innovation, Regional Development, Climate Change, and Circular Economy.
United States	<ul style="list-style-type: none"> ➤ USA has been a major player in BioEconomy policy with release of "National BioEconomy Blueprint" (2012), covering biotechnology and biomedicine. ➤ 2022 National Biotechnology and Biomanufacturing Initiative highlight ongoing efforts to enhance innovation and growth in the US Bioeconomy.
Japan	<ul style="list-style-type: none"> ➤ Japan's commitment to biomass utilization began with "Biomass Japan Strategy" (2002), revised in 2006 to include bioenergy and biomass towns. ➤ National Biomass Utilization Promotion Plan (2010) set targets for biofuels, and Japan's first dedicated BioEconomy strategy (2019, updated 2020) builds on its strong bio-industry and research capabilities.

4. What are the challenges in building a strong Bioeconomy in India?

Building a bio-economy encompasses various challenges spanning across policy, infrastructure, technological development, and socio-economic factors-

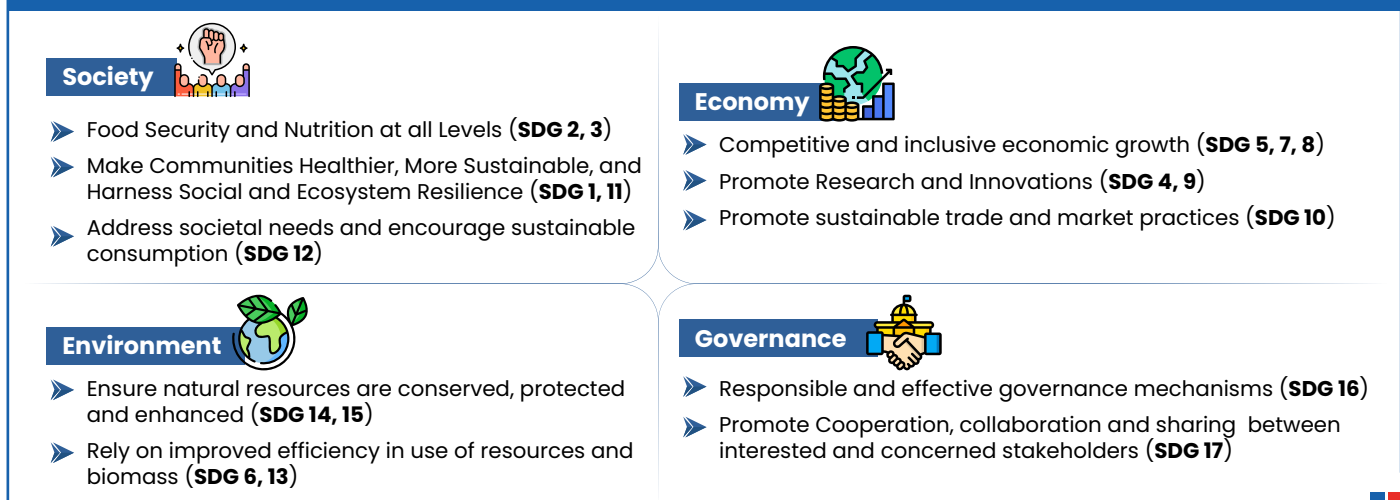
- **Regulatory:** The regulatory landscape in India is often fragmented, e.g. different agencies (DBT, FSSAI, etc.) have overlapping roles, leading to delays and confusion.
 - ▷ For instance, the approval process for genetically modified crops in India has been **controversial and time-consuming**, as seen with the case of Bt Brinjal.
 - ▷ Also, **complex and varying regulations** across different Indian states create operational hurdles.
- **Funding issues:** High upfront costs and long timelines for returns on bio-economy projects (e.g., bio-plastics, biofuels) make it difficult for start-ups and even established companies to secure sustained investment.
 - ▷ Further, the **return on investment in biotech can be uncertain** deterring private investors.
- **IP protection issues:** Securing intellectual property rights for innovations in biotechnology is complex, challenging, and slow-moving, discouraging innovation in bio-economy sectors. Further, **Section 3(d) of Patent Act hinders foreign direct investment in biotech sector** in India.
- **Bio-piracy concerns:** India's rich biodiversity makes it a hotspot for bio-piracy, where foreign companies exploit indigenous biological resources without proper benefit-sharing.
 - ▷ For example, US Patent and Trademark Office granted a patent after turmeric.
- **Limited Scalability:** Limited capacity in India to transform research leads into commercial products due to limited academia-industry linkages is one of the critical barriers to translational research.
- **Supply chain issues:** India's biotechnology sector remains dependent on global supply chains for essential raw materials, equipment, and advanced technologies.
 - ▷ Further, **availability of feedstock like agricultural residues can be unreliable** due to climatic conditions, land-use patterns, and competing demands (e.g., for food or fodder).
- **Competition:** India's bio-economy sector biotech **lacks scientific research and innovation in areas like synthetic biology, bioinformatics, and enzyme technology.**
 - ▷ Also, India faces stiff competition from countries (US, China, South Korea) with advanced biotech sectors impacting investment flows.
- **Impact on biodiversity:** Overexploitation of biological resources and transboundary movement of bio-based products can lead to **depletion of species and introduction of invasive alien species.**
 - ▷ Further, developing new bio-based products requires extensive utilization of genetic resources, such as crops and livestock, resulting in loss of genetic diversity.
- **Impact on land use:** Bio-economic activities like production and consumption can lead to land use changes. For example-
 - ▷ **Expansion of agricultural land to grow biofuel crops**, such as corn and sugar cane for bioethanol.
 - ▷ **Building bio-refineries in rural areas** to convert agricultural residues into bio-based chemicals leads to decrease in area under cultivation.
- **Skill gaps:** India faces a **shortage of professionals trained in bioengineering, molecular biology, genomics**, and other high-tech fields, further exacerbated by gap in academia-industry partnership.
- **Climate change:** Bioeconomy is threatened by climate risks, both sudden events like hurricanes and floods, and slow-onset changes such as shifting precipitation patterns.
- **Public perception:** Public scepticism about Genetically Modified Organisms (GMOs) and other bio-based innovations, such as lab-grown food or biofuels, can hinder the adoption of bio-economy products.
 - ▷ For instance, there has been significant **public opposition to GM crops in India**, leading to moratoriums on some GM food crops.

5. What can be done to strengthen India's future Bioeconomy?

To ensure that the benefits of biotechnology are maximised while minimising potential harms, careful planning, significant investment, strong regulatory frameworks, and active engagement with all stakeholders is required.

- **Updating regulatory frameworks:** Strategic reforms, harmonized with regulatory reforms and global standards, can help in facilitating production and commercialization of novel bio-based products.
 - ▷ To identify regulatory challenges and derive potential solutions, proactive engagement is needed with all stakeholders.
 - ▷ Further, ensuring sustainability requires **responsible land-use planning**.
- **International collaboration:** Foster partnerships with global biotech hubs and companies to access expertise, and markets.
 - ▷ For example, National Centre for Biotechnology Information can collaborate with European Molecular Biology Laboratory, DNA Data Bank of Japan to highlight strengths of Indian biotech sector on global platforms.
- **Public-private partnerships:** Encourage collaboration between government, academic institutions, and private companies to enhance and diversify sources of funding. For example, US Small Business Innovation Research program to fund collaborative biotech projects.
- **New Partnership Centres for Research (PaCeR):** They can be established for augmenting and strengthening institutional research capacity in areas of life sciences/biotechnology.
 - ▷ This will **boost research quality, aid in building cross disciplines linkages** to evolve robust interdisciplinary research programs.
- **Promoting start-ups:** Supporting Start-ups to propel their technology from proof of concept to manufacturing, and **create bio-innovation hubs to facilitate networking**, knowledge-sharing, and access to funding.
 - ▷ Enhanced focus on **new and emerging areas** and priority areas like Precision Medicine, CAR-T technology, Gene editing and therapy, etc. can help prepare for future technologies.
- **Enhance IP protection:** Strengthen IP laws and their enforcement to **encourage innovation and attract investment**. Set up single window clearance system for patent approvals and specialized IP courts to fast-track biotech patent disputes.
- **Encourage Sustainable Bioeconomy:** There is need for more intergovernmental cooperation and coordination to promote a sustainable bioeconomy and establish globally accepted sustainability criteria for the bioeconomy that are closely aligned with the Sustainable Development Goals (SDGs). (refer to Figure 5.1.)

Figure 5.1: 10 Principles for a Sustainable Bioeconomy



- **Skill development:** Invest in training and education programs to develop a skilled workforce, ensuring quality at par with global standards, integrate bio-economy-focused courses into university curriculums, to develop skilled workforce.
- **Rural bio-entrepreneurship:** Encourage rural bio-entrepreneurship and scale grassroots innovations by demonstrating viable, eco-friendly technologies for holistic, sustainable adoption.
 - ▷ **Foster scientist-farmer partnerships through participatory research**, linking labs with farms to develop innovative agricultural solutions.

- **Public trust:** Shift to data-driven communication, engaging SHGs, citizens, etc. to build public trust and boost acceptance of biotechnology solutions and foster development at grass root level.
- **Promoting Socio bioeconomy:** Socio-bioeconomy offers opportunities for generating innovative products, promoting sustainable economic growth and preserving biological, cultural and social diversity.

Box 5.1: In Conversation! Socio-Bioeconomy

Vinay

Hey Vini, have you heard about the emerging concept of Socio-Bioeconomy? It was suggested as a solution to Amazon forest fires.

No Vini! What is it?

It is a concept that acknowledges the connection between biodiversity and socio-cultural systems.

But how does it work exactly?

As a part of bioeconomy, it combines innovation, relationships with traditional communities and economic approaches surrounding job creation and income generation.

So basically it drives sustainable economic growth while preserving region's rich biodiversity and cultural heritage.

Yes. For example, Brazil's innovative 'socio-bioeconomy' model, is designed to transform agriculture, preserve traditional cultures, and drive climate and biodiversity action while generating jobs and fair compensation.

Vini

Conclusion

Bioeconomy holds the potential for sustainable growth by harnessing biological resources to address environmental, economic, and social challenges. While its potential is vast, challenges like resource scarcity, technological gaps, and policy alignment need to be addressed. Moving forward, a collaborative approach involving innovation, strong governance, and sustainable practices is essential to fully realize the bio-economy's benefits, ensuring a greener and more resilient future. It will help build a more prosperous, equitable, and sustainable development for current and future generations and achieve the target of **Viksit Bharat by 2047**.



TOPIC AT A GLANCE

Bioeconomy

- Refers to **production, utilization, conservation, and regeneration of biological resources**, including related knowledge, science, technology, and innovation, to provide sustainable solutions. (FAO)
- **Subsectors:** BioIndustrial (including Biomanufacturing); BioPharma and BioMedical; BioAgri; BioResearch and BioIT (BioServices) etc.



Significance of Bioeconomy in India's growth

- ⊕ **Economic Growth:** By 2050, the global BioEconomy expected to represent ~12% of projected global GDP.
- ⊕ **Food Security:** GM technology increased crop yields by 21%.
- ⊕ **Healthcare:** Development of new drugs, vaccines, etc.
- ⊕ **Employment:** Projected to create 35 million jobs by 2030.
- ⊕ **Emergence of Bio startups and Increase in Exports**
- ⊕ **Environmental benefits:** Promoting Circular economy; Lowering environmental pollution; Conservation of biodiversity; Eco-restoration; Biologizing industries; Climate action.



Challenges

- ⊕ **Regulatory:** Fragmented regulation and complex and varying regulations across states.
- ⊕ **Funding issues:** High upfront costs and long timelines for returns.
- ⊕ **IP protection issues and Bio-piracy concerns.**
- ⊕ **Limited Scalability:** due to poor academia-industry linkages.
- ⊕ **Supply chain issues and high global competition.**
- ⊕ **Potential adverse impact on biodiversity and land use.**
- ⊕ **Other issues:** Skill gaps; Climate change threats; Public scepticism etc.



Initiatives taken in India

- ⊕ **Policy:** BioE3 Policy; Sector specific Policies like National Mission on Bioeconomy, 2016; Draft National Biotechnology Development Strategy (2020-2025) etc.
- ⊕ **Schemes and initiatives:** Bio- RIDE Scheme; Biotech Science Clusters; Global Biofuel Alliance National Biopharma Mission; Production Linked Incentive (PLI) Scheme for Pharmaceuticals etc.
- ⊕ **Governance and Regulatory steps:** BRIC; BioRRAP; Intellectual Property (IP) Guidelines, 2023; Guidelines for Genetically Engineered Insects, 2023 etc.
- ⊕ **Regional:** Uttar Pradesh Pharmaceutical and Medical Devices Industry Policy 2023; Tamil Nadu's Ethanol Blending Policy etc.



Way Forward

- ⊕ **Updating regulatory frameworks:** Strategic reforms, harmonized with regulatory reforms and global standards.
- ⊕ **International collaboration:** Foster partnerships with global biotech hubs and companies.
- ⊕ **Public-private partnerships for diversified funding**
- ⊕ **New Partnership Centres for Research (PaCeR).**
- ⊕ **Promoting start-ups** with focus on new and emerging areas and priority areas.
- ⊕ **Enhance IP protection and Promoting Socio bioeconomy.**
- ⊕ **Other steps:** Rural bio-entrepreneurship; Skill development; Build Public trust; etc.

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