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NITI Aayog

NITI Frontier Tech Hub

Roadmap for Building India as a Leading BioEconomy Powerhouse by 2035

July 2026

Disclaimer

This roadmap has been prepared by NITI Frontier Tech Hub (FTH) in consultation with experts and stakeholders. The data used is from secondary sources. Any references to specific organisations, products, services or technologies does not attribute to endorsement but are only for illustrative purposes.

Acknowledgement

We express our sincere gratitude to Dr. Rajesh S. Gokhale, Secretary, Department of Biotechnology, his team and Shri B.V.R. Subrahmanyam, Former CEO, NITI Aayog for their invaluable contributions. Their guidance has been instrumental in ensuring that the roadmap remains both aspirational in its vision and firmly grounded in present realities.

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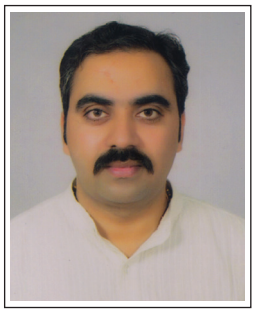

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Message

India's bioeconomy has entered a phase of rapid and substantive progress. One that many observers are calling a golden age of biology, comparable to the computing revolution of the 1970s. Just as that era transformed computation into a universal tool reshaping every industry, today's breakthroughs in genome editing, synthetic biology, AI assisted protein design, and precision fermentation are turning biology into a reliable platform for manufacturing and problem solving across medicines, materials, food, and agriculture. This transformation aligns with India's planning horizon for Viksit Bharat 2047. Strengthening the biotech ecosystem is central to enhancing domestic capabilities in pharmaceuticals and affordable vaccines, reducing dependence on imported fertilizers and industrial enzymes,advancing resilient agriculture, and building an export competitive bioeconomy rooted in India's scientific and manufacturing base. The government's BioE3 policy - Biotechnology for Economy, Environment, and Employment provides the framework for this effort. The opportunity before us is to elevate biotechnology from a sector of growth into a pillar of national competitiveness, public health security, climate resilience, rural prosperity, and high value employment.

The NITI Frontier Tech Hub's roadmap, Building India as a Leading Bioeconomy Powerhouse by 2035, is a call for mission mode national execution. By aligning research, regulation, capital, infrastructure, talent, and markets through focused BioMissions, India can move decisively from laboratory excellence to globally competitive products, platforms, and enterprises. With ambition, speed, and whole of government coordination, India can build a bioeconomy that advances Viksit Bharat, strengthens strategic autonomy, and delivers solutions not only for its own people but also for the world.

Prof. Gobardhan Das
Member, NITI Aayog

Foreword

Foremost, I express my sincere gratitude to NITI Aayog for its timely efforts in conceiving and publishing this important document for the Bioeconomy, underscoring the strategic importance of this sector to India's economic growth, technological leadership, and sustainable development.

India is among the few nations in the world with a dedicated Government department focused exclusively on biotechnology. Since its inception, the Department of Biotechnology (DBT) has played a catalytic role in shaping India's biotechnology landscape, fostering scientific excellence, enabling innovation, and building institutional frameworks that connect research, entrepreneurship, industry, and societal impact.

Over the past three decades, DBT has systematically strengthened every layer of the biotechnology value chain. Strategic partnerships such as India Alliance have nurtured world-class scientific talent and supported cutting-edge research. The establishment of the Biotechnology Industry Research Assistance Council (BIRAC) transformed the innovation ecosystem by creating a dedicated interface between academia, startups, industry, and government, catalyzing entrepreneurship and enabling a vibrant biotechnology startup movement. The National Biopharma Mission further strengthened the translational ecosystem by accelerating the development of vaccines, biotherapeutics, diagnostics, medical devices, and shared technology platforms, helping bridge the critical gap between laboratory discoveries and market-ready products.

Together, these investments created a robust innovation continuum—from scientific discovery to translation and commercialization. This ecosystem proved invaluable during the COVID-19 pandemic, enabling India to rapidly develop, manufacture, and deploy indigenous vaccines, diagnostics, and other healthcare solutions at an unprecedented scale.

Building on these foundations, DBT has recently established the Biotechnology Research and Innovation Council (BRIC), bringing together the collective strengths of its research institutions to create a coordinated framework for mission-oriented science, interdisciplinary collaboration, and accelerated translation. BRIC represents a new paradigm of collective intelligence, enabling institutions to work as an integrated innovation network rather than as individual entities.

In another landmark initiative, the Government has approved the BioE3 Policy—Biotechnology for Economy, Environment and Employment—to usher in a new era of high-performance biomanufacturing. The policy is already progressing from vision to implementation and seeks to transform healthcare, agriculture, food systems, energy, and environmental sustainability through cutting-edge biotechnology. Central to this effort is the creation of a national network of Biofoundries and Biomanufacturing Hubs that will provide advanced design-build-test-learn capabilities, automation, scale-up infrastructure, pilot manufacturing facilities, and translational platforms. These investments will significantly reduce the time from discovery to deployment, de-risk innovation, and enhance India's competitiveness in emerging bio-based industries.

Industry excels in product development, and Government support acts as a powerful force multiplier. However, disruptive innovation requires moving beyond incremental improvements and low-cost adaptations toward creating entirely new technologies and industries.

While frugal innovation has enabled India to become a global leader in affordable products, true technological leadership will depend upon our ability to translate deep-science breakthroughs into globally competitive products, platforms, and enterprises. The convergence of scientific excellence, translational capability, entrepreneurial energy, and advanced biomanufacturing infrastructure positions India uniquely to achieve this transformation.

The document outlines key missions and strategic priorities through a whole-of-government approach, bringing together multiple Ministries and Departments to pursue ambitious bioeconomy goals. Its recommendations provide a roadmap for strengthening research and innovation, expanding biomanufacturing capacity, fostering entrepreneurship, developing skilled human resources, and enhancing India's position in global biotechnology value chains.

I thank the members of the Expert Council for their invaluable contributions. DBT remains committed to implementing the multi-pronged strategy articulated in this report and to working closely with academia, industry, startups, investors, and international partners to emerge as a leading global bioeconomy and biomanufacturing powerhouse.

We look forward to working with all stakeholders in placing India at the forefront of the global biological age—creating economic opportunity, strengthening national resilience, advancing sustainability, and improving quality of life for people in India and across the world.

Dr. Rajesh S. Gokhale
Secretary, Department of Biotechnology

Foreword

The emergence of the bioeconomy is creating new pathways for economic growth, industrial competitiveness, sustainability, and strategic resilience. Across the world, nations are increasingly recognising biotechnology as a foundational capability that will influence future prosperity and geopolitical relevance. For India, the challenge is not simply to participate in this transformation but to shape it.

This document recognizes biotechnology as a strategic enabler of India's future growth, with applications spanning healthcare, agriculture, manufacturing, energy, and environmental sustainability. Its significance lies in providing a coordinated framework to align national priorities, institutional capabilities, and investments around a shared vision for the bioeconomy.

Further, it also underscores the urgency of action. Leading economies are already deploying coordinated national strategies to strengthen their positions in the emerging bioeconomy. India has a significant opportunity to establish leadership in areas such as advanced biologies, synthetic biology, precision fermentation, and AI-enabled drug discovery, but this window will narrow as global competition intensifies. Realizing this potential will require timely execution, sustained investment, and close coordination between the Centre, States, industry, and research institutions. As demonstrated by India's digital transformation, success will depend on our ability to combine vision with implementation at scale, enabling states to emerge as engines of biotechnology innovation, manufacturing, and employment generation.

The recommendations on National BioMissions, governance mechanisms, financing, and regulatory reforms offer a practical pathway to accelerate innovation, strengthen domestic capabilities, and create opportunities across states. As India advances towards the vision of Viksit Bharat 2047, a vibrant bioeconomy can drive economic growth, generate high-quality employment, enhance resilience, and position the country as a global leader in biotechnology and biomanufacturing.

I congratulate NITI Frontier Tech Hub, the Expert Council Members, and all contributors for producing this comprehensive roadmap. It offers a valuable strategic guide for policymakers, industry leaders, researchers, and investors working collectively to build India's future as a leading bioeconomy powerhouse.

Nidhi Chhibber
CEO, NITI Aayog

Foreword

Artificial intelligence has rightly captured the world's imagination. But the next mega-disruption is already taking shape alongside it — and it may be even larger in scope. What computing did to information, biotechnology is beginning to do to matter itself: how we make medicines, grow food, produce chemicals, materials and fuels, and safeguard human, animal and planetary health.

The implication is profound. In the coming decades, biotechnology will no longer remain a specialised sector. It will become a foundational layer of the twenty-first-century economy. Pharmaceuticals and agriculture are only the beginning. Energy, textiles, chemicals, construction materials, packaging, cosmetics and even electronics are being reimagined through biological processes that can be cleaner, more efficient and more sustainable than the industrial methods they replace.

The global race for leadership has already begun. The United States has adopted a whole-of-government approach to biomanufacturing. The European Union is linking biotechnology to industrial competitiveness and climate resilience. China is using successive five-year plans to industrialise at scale and secure critical supply chains. The lesson is clear: leadership in the biological age will not flow from scientific excellence alone. It will depend on integrated systems that align research, capital, regulation, skills, data, infrastructure and manufacturing. And it will accrue disproportionately to those who move early.

India enters this decade from a position of genuine strength. We have deep public research institutions, the world's largest vaccine manufacturing base, a globally trusted generics and biosimilars industry, a fast-growing biotech startup ecosystem, and a proven ability to deliver at population scale under pressure. The task now is to convert this foundation into a decisive, early and purposeful bid for global leadership.

That is the purpose of this roadmap. It sets out a ten-year strategy to move India from a fast-growing biotechnology sector to a globally significant bioeconomy — scaling from $195.3 billion today toward $691 billion by 2035 and $2.6 trillion by 2047. Its goal is to strengthen India's competitive advantages, secure resilience in medicines, food systems and critical bio-inputs, and ensure that in the biological age, India shapes the rules, markets and platforms of the future — rather than being shaped by them.

Debjani Ghosh
Distinguished Fellow,
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Executive Summary

India stands at a pivotal moment in the global biological century. In just a decade, the country's BioEconomy has expanded sixteen-fold from $10 billion in 2014 to **$195.3 billion in 2025** now contributing **4.8%** to national GDP.

This is no longer a story of promise alone; it is one of the demonstrated capabilities - validated by India's pandemic-era leadership in vaccines, the rapid rise of more than 10,000 biotech startups and a globally trusted BioPharmaceutical and BioIndustrial manufacturing base.

This Roadmap argues that the next phase must go far beyond incremental growth. With decisive, mission-mode execution, India can scale its BioEconomy to **$691 billion by 2035** and **$2.6 trillion by 2047** creating over **30 million high-value jobs** and positioning the country among the **world's top three biotechnology powers.**

It sets out a strategic proposition for India to transition from traditional biological R&D to AI-enabled biotechnology and next-generation biomanufacturing, driven by deeper collaboration across ministries, departments, academia, industry and startups. Early action would allow India not merely to participate in this transformation, but to shape the global rules, markets and platforms of the biological age-an upheaval likely to rival, and perhaps surpass, the disruption unleashed by artificial intelligence.

From Scientific Strength to Global Bio-Leadership

India enters this decade with rare strategic assets: deep public-sector research institutions, a mature vaccine and generics industry, rapidly expanding bio-industrial capacity, rich biodiversity and a fast-growing convergence between AI and biology. The BioE3 Policy anchored in Economy, Environment and Employment provides the organizing framework to convert these strengths into global leadership by breaking sectoral silos and tightly linking innovation to manufacturing, sustainability and livelihoods.

Globally, major powers are already moving at speed. The United States has adopted a whole-of-government approach to biomanufacturing; the European Union is tying biotechnology to climate and industrial competitiveness; China is deploying five-year plans to industrialize at scale. The common learning from global best practices is that leadership flows not from research alone, but from integrated systems that align capital, regulation, skills, data and production. India now has a narrow but historic window to leapfrog from being the world's most trusted supplier of affordable healthcare products to becoming the world's Bio-Capital.

The next frontier of biotechnology will be defined by deep convergence with AI, robotics, computational biology and biosensor networks. Globally, advances in biologics, cell and gene therapies, precision fermentation, synthetic biology and climate-smart agriculture are scaling only through AI-driven design tools, robotic bio-foundries, automated DBTL cycles and sensor-rich bioprocessing. BioE3 must therefore embed digital and computational infrastructure as foundational public goods. Across all sectoral growth trajectories, strong integration of AI, computational biology, robotics and biosensor-enabled measurement systems will be essential to deliver the speed, precision and scalability needed for next-generation biotechnology to achieve impact at scale.

All sectoral growth trajectories assume strong integration of AI, computational biology, robotics and biosensor-enabled measurement systems that enable speed, precision and scalability.

A Mission-Driven Strategy for Scale

The roadmap proposes a decisive shift from fragmented programs to National BioMissions with time-bound delivery. Flagship efforts being suggested are:

1. **GeneIndia -** To make affordable gene and cell therapies and precision diagnostics available to Indian patients, built on population-scale genomic capabilities.
2. **AgriBio 2.0 -** To deliver climate-resilient, farmer-owned crop varieties and quality-assured bio-inputs that improve farm profitability and reduce chemical dependence.
3. **BioX Foundry -** To turn India's industrial biotech innovations into commercial-scale products, building a globally competitive base of synthetic-biology enterprises.
4. **One Health Grid -** To enable AI-assisted disease detection and coordinated response to emerging infectious diseases, zoonotic threats and AMR across human, animal and environmental health.
5. **Marine Biotechnology -** To grow India's marine-derived exports and coastal bioeconomies through seaweed cultivation, marine bioproducts and blue-economy innovation.
6. **BioPharmaNext -** To establish India as a global hub for affordable, next-generation biologics, biosimilars, vaccines, and cell and gene therapeutics.

S. No	Mission Name	Focus Area	Lead Agency	Outcome by 2035
1.	**GeneIndia**	Cell/gene therapies	DBT + ICMR	Affordable gene cures
2.	**AgriBio 2.0**	CRISPR crops, BioInputs	DBT+ ICAR + MoA&FW	Climate-resilient crops
3.	**BioX Foundry**	DBTL innovation platforms	CSIR + DBT	100 SynBio startups
4.	**One Health**	Grid Zoonosis+ BioSecurity	ICMR + MoHFW	Early detection + outbreak preparedness
5.	**Marine Biotechnology**	Marine biotech, algae	MoES + BIRAC	Exports + blue economy
6.	**BioPharmaNext**	Vaccines, biologics, biosimilars, AI-driven drug discovery	DBT + DOP + CDSCO	Global hub for affordable, next-generation biologics

These are designed to build sovereign capabilities across advanced therapeutics, climate-resilient agriculture, synthetic biology platforms, pandemic preparedness, blue-economy innovation and next-generation biologics. Together, these missions form a coherent national architecture: genome-to-clinic pipelines for affordable gene therapies; CRISPR-enabled crops and bio-inputs for food and climate resilient crops; AI-driven biofoundries to shorten innovation cycles; digitally linked surveillance systems to detect biological threats early; and globally competitive biopharma hubs capable of supplying advanced medicines at scale.

To ensure delivery, the Roadmap calls for following empowered cross-ministerial governance structures:

1. **An Empowered Committee on National BioMissions**

   Establish a high-level, inter-ministerial committee to drive coordination, fast-track decisions, and monitor implementation of national bioeconomy missions.

2. **A National BioData Council**

   Create a central body to govern, standardize, and enable secure sharing of biological and health data across sectors.

3. **A BioEconomy Investment & Policy Forum**

   Set up a dedicated platform to align public and private investments, policy priorities, and global partnerships in biotechnology.

4. **A Dedicated Bio-IP Accelerated Pathway**

   Establish a specialized accelerated pathway to streamline intellectual property (IP) filing, protection, and translation for biotechnology innovations. These measures will align budgets, streamline regulatory processes, mobilize private capital, and strengthen the protection of Indian intellectual property, thereby facilitating technology transfer and accelerating industry adoption of biotechnology innovations.

These will align budgets, streamline regulation, mobilize private capital, protect and commercialize Indian intellectual property.

Financing the Leap: From Prototype to Plant-Scale

A central proposal is the creation of a **₹50,000-crore BioEconomy Growth Fund (2026–2035)** to close India's most dangerous gap - the "valley of death" between proof-of-concept and manufacturing at scale. Anchored within the national RDI framework, this fund would deploy blended finance, catalytic equity and infrastructure support for biomanufacturing, advanced therapeutics, fermentation platforms, biomaterials, diagnostics and synthetic biology.

Coupled with targeted PLI-style incentives for biomanufacturing and reforms to accelerate regulatory approvals, this financial engine is intended to convert India's laboratory excellence into export-driven BioManufacturing leadership reducing import dependence, strengthening health and food security and anchoring high-value global supply chains on Indian soil.

Reforming Regulation for the Biological Age

Speed, predictability and scientific rigor in regulation will determine whether capital flows to India or bypasses it. The Roadmap therefore recommends differentiated approval pathways for frontier modalities - cell and gene therapies, synthetic biology, AI-designed drugs through regulatory sandboxes, a standing reform task force, modernization of CDSCO and biotech-specific patent protection measures to back IP-driven investment and technology translation.

Building the Talent to Lead

India's bioeconomy ambition ultimately rests on the strength of its people. The sector already employs over **3.3 million professionals** and supports nearly **12,000 startups**, yet with only around **259 researchers per million population** and roughly a quarter of higher-education enrolment in STEM, the talent pipeline remains too thin to sustain leadership in the biological age. The Roadmap therefore calls for a decisive strengthening of bioscience leadership and the talent pipeline: revitalizing undergraduate and postgraduate biotechnology education, expanding PhD and post-doctoral programmes with internationally benchmarked fellowships, and building frontier skills in bioinformatics, AI-driven biology, regulatory science and advanced biomanufacturing. Equally important are experiential and immersion-based learning, re-entry pathways for diaspora scientists, and a vibrant entrepreneurship ecosystem offering mentorship, incubation and commercialization support. By investing in people as deliberately as in infrastructure and capital, India can convert its demographic advantage into a durable source of scientific leadership — and ensure that the more than **30 million high-value jobs** envisaged by 2035 are matched by the skilled workforce needed to fill them.

A Call to National Action

This roadmap is ultimately a call to treat biotechnology as core national infrastructure on par with digital public goods or energy systems. With BioE3 as its compass and mission-mode execution as its engine, India can do more than scale: it can define standards, shape markets and ensure that the benefits of the biological revolution healthcare, sustainability and prosperity flow not just to its own citizens, but to the world.

The coming decade will decide whether India shapes the global bio-economy—or is shaped by it. This roadmap sets out the actions required to ensure that by the end of this decade, India stands firmly as a leader in the biological age.

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1. INDIA BIOECONOMY PROJECTIONS – 2035 AND BEYOND

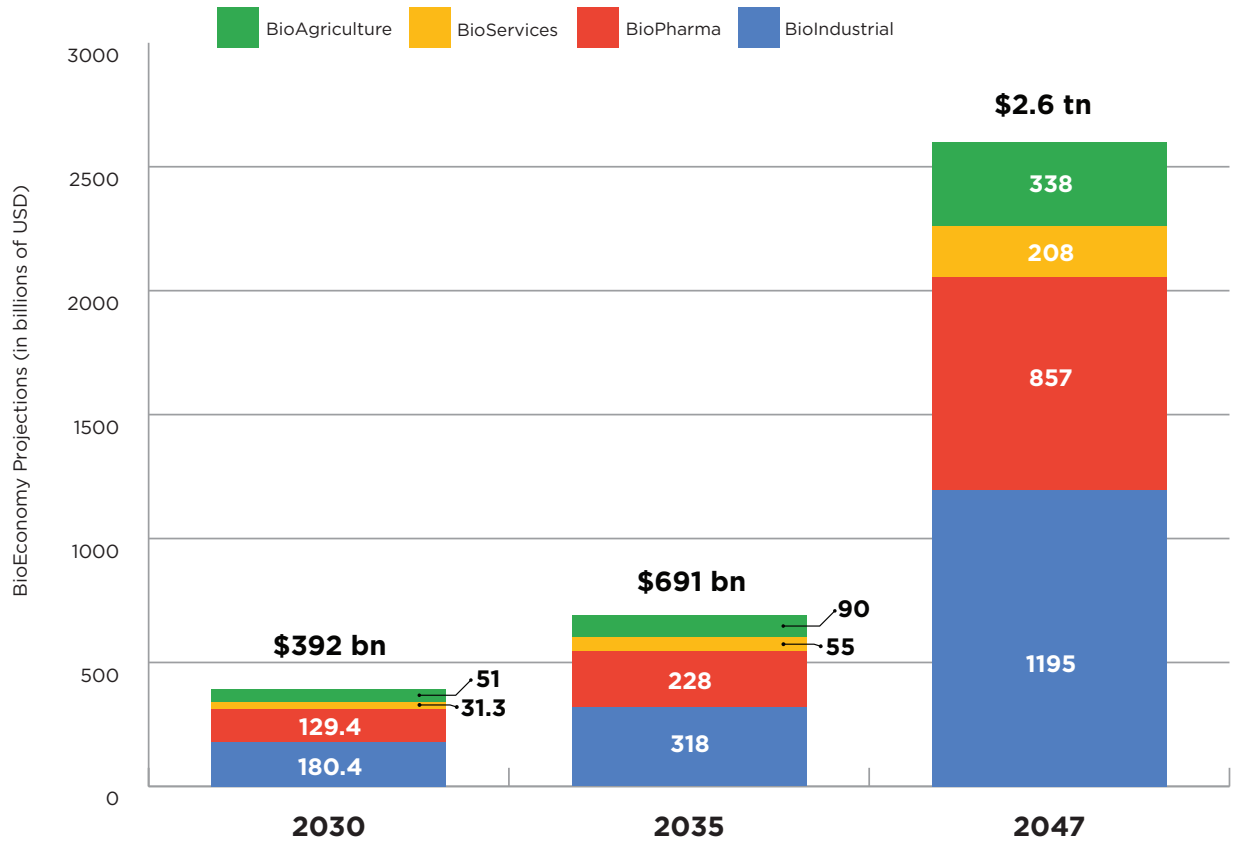
India's BioEconomy has grown 16-fold in the past decade, from **$10 billion in 2014** to **$195.3 billion in 2025**, contributing **4.8% to the national GDP**.

The projected expansion of India's BioEconomy assumes the integration of AI-native biology, computational modelling, digital twins and data-driven biosystems engineering. Computational biology will shorten discovery cycles, reduce cost of scale-up and strengthen India's competitiveness across BioPharma, BioIndustrial, BioAgriculture and BioIT.

Building on this foundation, the nation has set formidable targets to reach:

2030	2035	2047
$392 billion Contributing 4-4.5% to a projected $8 trillion GDP	**$691 bn** Contributing 5-6% to a projected $11 trillion GDP. Generate over 30 million high-tech jobs. Establish 15 globally competitive biotech companies.	**$2.6 tn** Contributing 8-10% of an envisaged $30 trillion GDP

1.1 BioEconomy Projections 2030-2047 (Segment-wise)



(Source: ABLE Projection based on the current BioEconomy Report (IBER 2025) and envisaged estimates based on the future potential)

1.2 Sector-by-Sector Transformation

Sector	2030	2035	2047	Key Drivers
BioIndustrial	$180.4 bn	$318 bn	$1195 bn	Biofuels, Biogas, Bio-based chemicals, Smart Proteins, Enzymes, Biopolymers, Carbon Capture Technologies, Probiotics, Food Grade Media, Bioplastics, etc.
BioPharma	$129.4 bn	$228 bn	$857 bn	Precision Medicines, Monoclonals, Vaccines, Therapeutic Enzymes, Biosimilars, Microbiome Therapeutics, Peptide Drugs, mRNA Therapies, APIs by Fermentation, CAR-T, CGTs, Adjuvants, Stabilizing Agents (Albumin), Viral Vectors, Cell Culture Media, Personal Care Products
BioIT/Research	$31.3 bn	$55 bn	$208 bn	Bio-AI, Multi-Omics-Genomics, Proteomics, Metabolomics as Services, Cheminformatics, Bioinformatics
BioAgri	$51 bn	$90 bn	$338 bn	Gene-edited Crops, Biopesticides. Biochar, Biofertilizers, Precision farming and Biostimulants

(Source: ABLE Projection based on the current BioEconomy Report (IBER 2025) and envisaged estimates based on the future potential)

2. INDIA BIOECONOMY: CURRENT SITUATION ANALYSIS AND GLOBAL BEST PRACTICES

2.1 Anchored in Legacy, Guided by BIO-E3

India's biotechnology journey reflects four decades of sustained and deliberate policymaking. It began with the Technology Policy Statement of 1983 and the establishment of the Department of Biotechnology (DBT), laying the institutional foundations for modern life sciences in the country. Over successive decades, National Biotechnology Development Strategies issued in 2007, 2015–2020 and 2021-2025 has expanded the sector's ambitions from research capacity-building to translation, commercialization and industrial deployment. Some of the key initiatives of the DBT which has catapulted the growth of the sector and has positioned India as one of the top biotech destinations globally are:

2.1.1 **Establishment of BIRAC -** As the model Industry-interface organization of DBT which created and ignited the biotech startup ecosystem in the country leading to supporting over 4500 innovators, establishing over 95 incubation centers with an outcome of 800 products in the market by many first-generation entrepreneurs.

2.1.2 **Genome India Program –** Cataloging the Indian population genome for leadership in precision healthcare.

2.1.3 **National Biopharma Mission –** In partnership with World Bank which catalyzed the biopharma industry and led to development and commercialization of affordable, indigenous, first of its kind healthcare products from vaccines (two in national immunization programs - Rotavac and Cervavac) to diagnostics to medical devices (MRI scanners) and instruments (perfusion bioreactors).

2.1.4 **Mission Covid Suraksha –** Led to the development/augmentation of five Covid vaccines (Zycov-D, Corbevax, Gemcovac, Incovacc) based on novel technology platforms leading to India's becoming *"Atmanirbhar"* in vaccinating the entire population in the pandemic and strengthen pandemic preparedness for mitigation of future risks.

This evolution has now culminated in the BioE3 Policy anchored in Biotechnology for Economy, Environment and Employment which provides a unifying national framework to align biotechnology with India's Viksit Bharat 2047 vision. BioE3 signals a decisive shift: from siloed sectoral programs to convergence-driven development; from laboratory discovery to large-scale manufacturing; and from narrow industrial metrics to inclusive growth, sustainability and strategic autonomy.

Collectively, these policy phases chart India's transformation from a science-led biotechnology ecosystem to one increasingly oriented toward economic value creation and job generation - moving decisively from Lab to Market to Livelihood. The national ambition is no longer confined to supplying affordable medicines to the world. It is to shape the next generation of solutions across BioIndustrial manufacturing, BioPharma innovation, BioAgriculture, BioEnergy and Bio-AI convergence.

The digital and computational biology must form the backbone of India's biotechnology architecture. This includes national multi-omics datasets, sovereign biological compute capacity, AI-driven modelling engines, high-throughput automation and sensor-enabled real-time biological measurement. These infrastructures are now indispensable for Genomic Medicine, CGTs, SynBio, Precision Agriculture and Industrial Biomanufacturing. Bio-AI hubs are one of the enablers for building data-driven, cutting-edge, programmatic research support for the Biomanufacturing initiative. The outcomes are expected to provide critical and novel research leads impacting Health, Agriculture and Environment.

India's biotechnology evolution reflects a clear progression:

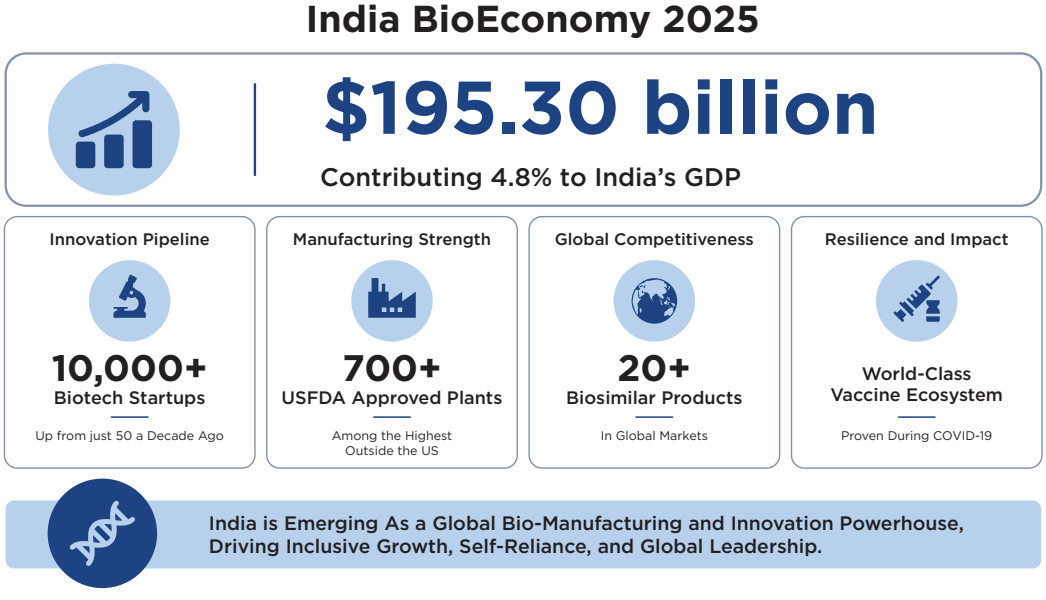
Era	Strategic Milestone	Core Objective	Outcome / Next Phase
1986–2007	DBT Formation & NBDS 2007	Build national biotech capability	Institutional base, biotech parks, academic networks
2015–2020	NBDS II: "Empowering India through Biotechnology"	Integrate health, agriculture, energy	Translational research, bio- clusters, BIRAC ecosystem
2021-2025	NBDS III	Expand BioEconomy to $300 Bn	Deep-tech and data-driven innovation
2024	BioE3 Policy	Sustainable technologies for BioEconomy, BioEnvironment & BioEmployment	High performance Biomanufacturing for bioproduction and bioeconomy driven by integration of AI in biology, strengthening of biological research institution network-BRIC

By positioning biotechnology as core national infrastructure rather than a narrow industrial vertical, BioE3 elevates the sector to a strategic pillar of India's development model and linking innovation directly to productivity, livelihoods, competitiveness and geopolitical relevance.

2.2 India BioEconomy Trajectory: Current Situation Analysis and Way Forward

India enters the next phase of its BioEconomy journey from a position of proven strength. The country combines a formidable scientific base, globally competitive manufacturing capacity and one of the world's fastest-growing innovation ecosystems. Its pandemic-era response, delivering vaccines at population scale while supplying much of the developing world was not an isolated achievement, but the culmination of decades of institutional investment and industrial learning.

This performance was not an anomaly, but the result of capabilities built over decades and validated under unprecedented stress. With this foundation, India is well positioned to scale its bioeconomy from current **$195.3 billion to $2.6 trillion by 2047**, embedding biotechnology as a central driver of economic growth with strategic autonomy and employment generation.



(Source: India BioEconomy Report 2025)

This scale and momentum reflect not only market growth, but the structural maturation of India's biotechnology ecosystem, from research to manufacturing, to global deployment.

The Department of Biotechnology (DBT) and Biotechnology Industry Research Assistance Council (BIRAC) have set a formidable target for the BioEconomy to reach **$300+ billion** by **2030**. This is a steppingstone towards a larger projected ambition of achieving a **$691 billion BioEconomy** and **$100+ billion** in biotech exports by **2035.** This milestone would position India among the top three global biotech players.

This is just the beginning.

With the right push, India can reach

2030	2035	2047
$392 billion 4-4.5% GDP Contribution Market leadership established	**$691 billion** 5-6% GDP Contribution Global bio-hub status	**$ 2.6 trillion** 8-10 % GDP Contribution Bio-superpower achieved

It will also generate 30 million+ high-value jobs.

Recent Growth Drivers

Over the past four years, India's BioEconomy has grown at nearly 18% annually, powered by multiple reinforcing engines.

The BioIndustrial segment has expanded rapidly, driven by industrial enzymes, bioplastics and fermentation platforms, alongside the E20 ethanol blending mandate that has catalysed biofuel production at scale. In parallel, the pandemic accelerated the BioPharma sector - boosting vaccine manufacturing, biosimilars and biologics while positioning India as a preferred global destination for contract research and manufacturing through its CRO and CDMO ecosystem.

The Biotechnology Research and Innovation Council (BRIC), an initiative of DBT, is a leading network of elite biological research institutions in the country. These top-tier institutions have synergized their efforts to maximise the impact of biotechnology. Through key strategic partnerships, both nationally and globally, with academia and industry, BRIC is transforming inter-institutional and interdisciplinary research, research training, and the commercialisation of research.

Key Growth Drivers of India's BioEconomy

- **~18% annual growth** over the past four years.
- **BioIndustrial surge** driven by enzymatic and microbial solutions bioplastics & fermentation platforms.
- **E20 ethanol mandate** accelerating large-scale biofuel production.
- **BioPharma expansion** through vaccines, biologics & biosimilars post-COVID.
- **Global CRO/CDMO leadership** strengthening India's position as a preferred innovation and manufacturing hub.

Together, these drivers have resulted in broad-based, multi-sectoral growth across India's BioEconomy. The sector-wise distribution of the BioEconomy during 2020–2024 underscores the diverse and complementary contributions of BioIndustrial, BioPharma, BioAgri, BioEnergy and BioServices positioning India as a future global leader in biotechnology and setting the foundation for the next phase of scale and value creation (Source: India BioEconomy Report 2025 & 2026).

2.3 Policy and infrastructure Enablers

India's rapid expansion of the bioeconomy - rising to **$195.3 billion by 2025** reflects coordinated action by the Centre and states to strengthen financing, biomanufacturing, regulation, infrastructure and talent pipelines. Central initiatives supplied the catalytic capital and national frameworks: large-scale incentive programs (including successive Production-Linked Incentive tranches for pharmaceuticals, APIs and medical devices) and targeted funds, de-risked manufacturing investments, encouraging firms to move from commodity supply into higher-value biologics, vaccines and biomanufacturing. PLI-style support and coordinated industrial policy are credited with attracting large investments and boosting production and exports across life-sciences value chains.

Physical and innovation infrastructure supported by central schemes multiplied entrepreneurial activity. The National Biotech Park scheme and DBT/BIRAC incubation programs financed biotech parks, incubation centers and translational facilities across states. This catalyzed start-up formation and manufacturing unit clusters. These shared assets reduced CapEx barriers for young entrepreneurs, enabling many to scale rapidly to commercialize into domestic and global markets.

State governments amplified national momentum with locally tailored life-sciences policies, land and tax incentives and single-window facilitation. States such as Karnataka, Gujarat and Telangana rolled out comprehensive biotechnology policies, created biotech parks and eased approvals to attract manufacturing and R&D investment. Hyderabad and Bengaluru emerged as major life-sciences hubs, drawing global firms and large capital commitments. State initiatives focused on enabling talent with skill development programmes, providing subsidised land and utility support and forging industry-academia linkages. These initiatives compounded national measures to expand capacity and outputs.

2.4 SWOT Analysis of India's BioEconomy

Key Strengths

- **World's largest vaccine manufacturers and global leader in Generics.**
- **Biosimilars and BioPharma innovation. India is the trusted engine of affordable and scalable healthcare solutions for the world.**
- **Strong public research institutions backbone (BRIC, CSIR, DBT, DST, ICAR, ICMR, NIF, NRDC, TIFR and institutes like IISc, IITs, IISERs).**
- **BIRAC ecosystem: 4500+ startups, 100+ incubators.**
- **Biodiversity wealth: Marine, Agri, Microbial, Faunal.**
- **Focused alternative energy sources to reduce energy dependency – BioFuels, BioCNG from agriculture residues, MSW, pressmud, etc.**

Key Challenges

- **Low mid/late-stage capital access (Series A/B crunch).**
- **Regulatory complexity and multi-agency approval processes that slow innovation across agriculture, pharma and synthetic biology — pointing to the need for clearer, faster and more internationally aligned pathways, particularly for new-generation products such as advanced therapies, alternative proteins, probiotics and enzyme-based manufacturing.**
- **Limited GMP/GLP Biofoundry and scale-up infrastructure.**
- **High production cost due to imported raw material dependence.**
- **Limited validated animal models and translational platforms.**
- **Inadequate clinical trial networks and translational centres.**
- **Fragmented patient and disease data.**
- **Limited access to and preservation of biological resources.**
- **Weak regulatory science and safety evaluation capacity.**

Key Opportunities

- **Convergence of Biology and Engineering to scale Bioprocesses.**
- **AI + Biology convergence.**
- **CRISPR crops for climate resilience.**
- **Fermentation and sustainable bio-manufacturing.**
- **Export-oriented Bioplastics, Bioactives, Biocatalytic Enzymes.**
- **Deep-tech VC momentum for Healthcare, Food, Agriculture.**
- **AI-robotics-biosensor convergence enabling autonomous and continuous biomanufacturing, improving yields, reducing costs and accelerating scale-up across sectors.**

Key Threats

- **Low-cost Chinese Biotech imports (Biocatalytic Enzymes, CRISPR kits, reagents).**
- **Geopolitical risks in IP, apprehensions over dual-use technologies and talent flight.**
- **Stringent Biodiversity Act, a deterrent for biotech startups.**
- **Absence of support to counter prolonged gestation and capital lock-in in Biopharma.**

3. GLOBAL BENCHMARKING: HOW THE US, EU AND CHINA ARE APPROACHING THE BIOECONOMY

The global BioEconomy is rapidly transforming as nations, increasingly leveraging biotechnology to achieve economic growth, sustainability, improved healthcare outcomes and climate resilience. According to World BioEconomy Forum, projections indicate substantial expansion, with global BioEconomy contributions surging from **$4 trillion in 2025 to** over **$30 trillion by 2050**, representing nearly **13% of the estimated $228 trillion** global GDP. Emerging markets, particularly India, China and Indonesia, are expected to be significant growth drivers. As per the World in 2050 report, E7 economies, including India, forecasted to increase their share of world GDP from approximately 35% to nearly 50%, where the BioEconomy will play a pivotal role.

3.1 Global Progress and Best Practices

Across major economies, the bioeconomy has moved from strategy formulation to structured implementation.

- In the **United States**, bioeconomy policy is now anchored in a whole of government approach under the Executive Order on Advancing Biotechnology and Biomanufacturing (2022), with a clear focus on expanding domestic biomanufacturing capacity, strengthening supplychain resilience and coordinating federal action across healthcare, energy, agriculture and security domains. Emphasis is placed on scaling production infrastructure and addressing workforce and standards gaps, rather than R&D alone.
- The **European Union** has progressed through successive bioeconomy strategies from vision-setting to execution. Its most recent Strategic Framework (2025) positions the bioeconomy as a driver of both industrial competitiveness and sustainability, supported by strong measurement systems, regional implementation through action plans and integration with circular economy and climate policies. The EU experience highlights the role of consistent indicators, regional delivery mechanisms and regulatory coherence in translating biobased innovation into economic outcomes.
- **China** represents a different pathway, characterised by plan-led industrial scale-up. Through its 14th Five-Year Plan for Bioeconomy Development (2021–2025), China identifies biotechnology and biomanufacturing as strategic sectors, links industrial expansion directly with national development priorities and explicitly integrates biosecurity governance with economic and industrial objectives. This model demonstrates how long-term planning, manufacturing-led scale and regional pilot zones are used to accelerate deployment and reduce dependence on external supply chains.
- **Australia's** bioeconomy follows a translation-led, industry-aligned model, where strong research capability is closely linked to commercialization. While there is no single unified national bioeconomy strategy, the sector is advanced through frameworks such as the National Reconstruction Fund, Modern Manufacturing Strategy, and Industry Growth Program, which prioritise biotechnology, medical manufacturing, and bio-industrial scale-up. The bioeconomy is estimated at **AUD 100–120 billion (USD ~65–80 billion)**, spanning biopharma, medtech, agri-biotech, and industrial biotechnology. Australia has built global strengths in clinical trials, vaccine development, and precision medicine, supported by a robust regulatory environment and strong IP systems. Institutions like CSIRO play a central role in bridging research and industry, particularly in synthetic biology and digital biology.

  A defining feature of Australia's approach is its focus on translational infrastructure and global integration, including clinical trial networks, innovation precincts, and emerging biomanufacturing capabilities. In line with global trends, Australia is investing in AI-enabled drug discovery, bioinformatics, and advanced bioprocessing, recognising digital bio-infrastructure as critical for competitiveness.

Across these models, a growing convergence around a few best practices is noted: treating biomanufacturing as the core translation layer between research and economic value; using targeted finance and derisking instruments to crowd in private capital; and embedding measurement of value added, jobs and productivity within governance frameworks. Global experience suggests that sustained leadership in the bioeconomy emerges not from isolated investments in research, but from integrated systems that align manufacturing capacity, standards, skills, finance and data-driven monitoring.

A key global learning is the centrality of computational biology, AI-enabled design platforms, automated bioreactors and biosensor-based quality systems in achieving biomanufacturing scale and leadership. Leading economies treat digital bio-infrastructure not just as lab science but as strategic assets.

BioEconomy targets: Global Positioning and Strategic Implications

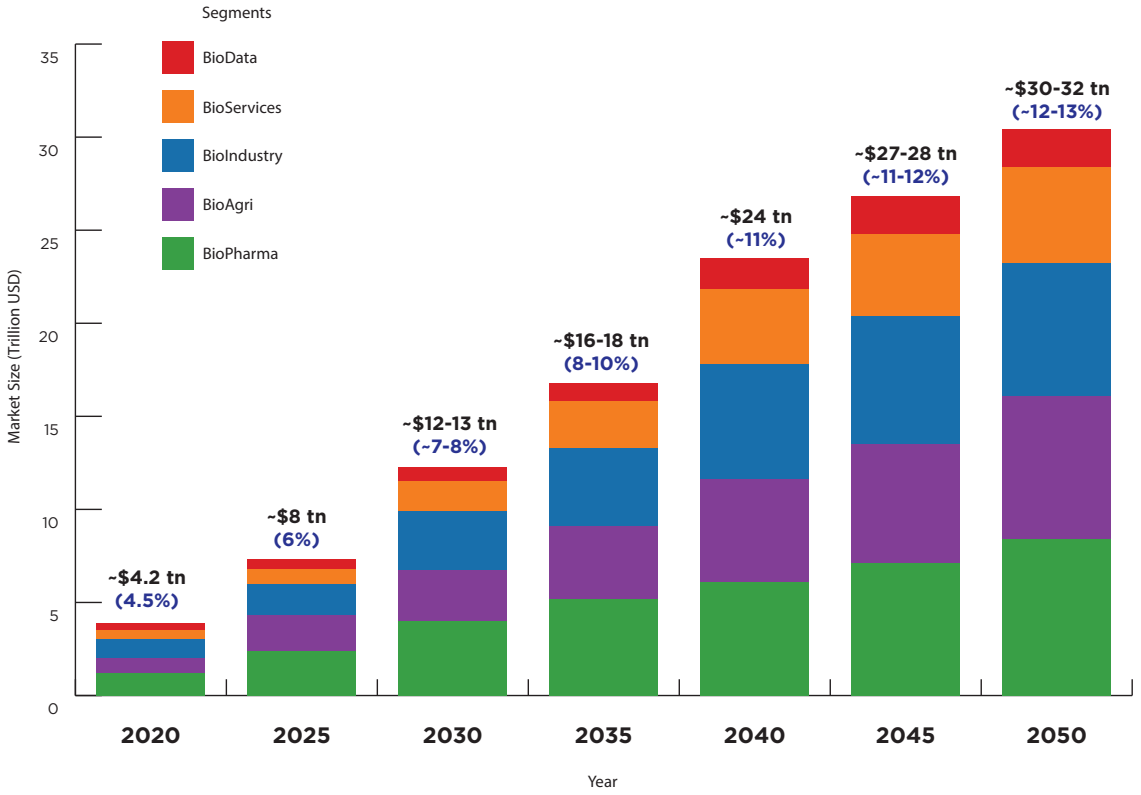
Country	Current Size	% of GDP	2040 Target	Focus Sectors
USA[1,6]	$950 bn	~5%	$3.5 tn	SynBio, AI Biology
EU[2]	$2.6 tn	~7.5%	$6 tn	Circular BioEconomy
China[3]	$500–600 bn	~4%	$2 tn	Gene editing, industrial enzymes
Brazil[4,6]	$300 bn	~10%	$600 bn	Bio Ethanol, Biodiversity
India[5]	$195.3 bn	4.8%	$ 1.36 tn	Bio Industrial Bio Pharma, Bio Agri
Australia[6]	$65-80 bn (est.)	~3-4% (est.)	~$150-200 bn (Indicative trajectory)	Biopharma, MetTech, AgriBiotech, Synbio, Clinical Research

Global BioEconomy Forecast

Year	Global BioEconomy Size	% of Global GDP	Source[7]
2020	~$4.2 tn	4.5%	OECD, EU JRC
2025	~$8 tn	6%	McKinsey, BIS
2035	~$16–18 tn	8–10%	GBS 2023, FAO
2050	~$30–32 tn	~12–13%	WB, FAO, BCG

1 United States: USDA BioPreferred Program; National Academies of Sciences
2 European Union: European Commission – Knowledge Centre for Bioeconomy
3 China: China Bioeconomy Development Plan (2022–2035)
4 Brazil: Ministry of Science, Technology and Innovation (MCTI)
5 IBER 2026 and ABLE's projections.
6 ABLE compilation; figures represent indicative estimates derived from multiple publicly available sources and should be interpreted as directional rather than official national statistics.

Projected BioEconomy Share in Global GDP (2020–2050)[7]



- Biotechnology leadership is now a time-bound geopolitical and economic opportunity.
- The coming five years will determine whether India merely scales or shapes the biological century.
- With BioE3 as the organising framework, India has the scientific depth, entrepreneurial energy, manufacturing base and policy momentum to emerge as the world's Bio-Capital.
- What is required now is mission-mode execution at national scale.

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Disclaimer: The segment-wise coloured bars represent analytical estimates of the projected global bioeconomy composition, developed using current industry composition, expected technology adoption trends, and published global bioeconomy outlooks from the FAO, McKinsey, OECD, the World Bank, and the Global Bioeconomy Summit. They are intended only for illustrative purposes and **do not represent official segment-wise projections** from the cited organizations.

4. KEY RECOMMENDATIONS TO ACCELERATE INDIA'S BIOECONOMY TRANSFORMATION

To realise India's **$2.6 trillion** BioEconomy vision by **2047**, the country must move from fragmented initiatives to a coordinated national execution architecture. This will require five mutually reinforcing interventions: mission-mode national BioMissions to scale priority sectors; empowered committees to drive cross-ministerial coordination and evidence-based investment decisions; regulatory reforms to accelerate approvals while ensuring safety and trust; a strengthened bioscience leadership and talent pipeline; and a **₹50,000 crore BioEconomy Growth Fund** to support innovation, scale-up, infrastructure and biomanufacturing. Together, these interventions can position India not merely as a fast-growing biotechnology market, but as a globally significant bioeconomy leader.

India Bioeconomy Key Strategic Interventions

National Bio-Missions

- GenIndia
- AgriBio 2.0
- BioX Foundry
- One Health Grid
- Marine Biotechnology
- BioPharmaNext

Empowered Committees

- Empowered Committee on National BioMissions
- National BioData Council
- BioEconomy Investment Forum
- BioIP & Innovation Evaluation Agency

Regulatory Reforms

- Regulatory Sandbox
- Streamlined Approval Framework
- CDSCO Modernization
- AI-led Regulatory Systems

Bioscience Leadership & Talent

- Strengthen Public Institutions Network
- Strengthen PhD & Postdoc Programs
- Enhanced Research Fellowships
- Build Science Leaders, not just Graduates
- Experiential & Immersion Learning
- Postdoc Entrepreneurship Programs

₹50,000 Crore Fund (2026–2035) — BioEconomy Growth Fund

- Focus areas: Innovation, Scale-up, Infrastructure
- Mid-to-Late Stage Funding
- Viability Gap Financing
- Blended Finance Instruments
- BioManufacturing Infrastructure
- PLI for Biomanufacturing

4.1 Create National Bio Missions Through Time-Bound Execution Plans

India currently has multiple biotechnology-related missions and initiatives being implemented at various stages by DBT, DST, ICMR and other agencies. While these efforts have significantly strengthened the ecosystem, there is a need to consolidate and align them under a more coordinated national framework.

Going forward, India should anchor its next phase of growth through a focused set of nationally coordinated BioMissions, each backed by 10-year implementation roadmaps, ring-fenced budgets, clear lead-ministry accountability, and real-time outcome monitoring.

These missions should evolve beyond grant-based programmes into integrated delivery platforms, combining R&D, manufacturing scale-up, regulatory alignment, workforce development, and assured procurement pathways to drive measurable outcomes.

Proposed National Bio-Missions and Expected Outcomes

Large-scale and multi-disciplinary effort required to grow India's BioEconomy with the aim to develop new products and create a supportive ecosystem for innovation demands national-level organisations.

S. No	Mission Name	Focus Area	Lead Agency	Outcome by 2035
1.	GeneIndia	Cell/gene therapies	DBT + ICMR	Affordable gene cures
2.	AgriBio 2.0	CRISPR crops, BioInputs	DBT + ICAR + MoA&FW	Climate-resilient crops
3.	BioX Foundry	DBTL innovation platforms	CSIR + DBT	100 SynBio startups
4.	One Health	Grid Zoonosis+BioSecurity	ICMR + MoHFW	Early detection + outbreak preparedness
5.	Marine Biotechnology	Marine biotech, algae	MoES + DBT	Exports + blue economy
6.	BioPharmaNext	Vaccines, biologics, biosimilars, AI-driven drug discovery	DBT + DOP + CDSCO	Global hub for affordable, next-generation biologics

4.1.1 GeneIndia: Building India's Affordable Cell & Gene Therapy Ecosystem

India faces a substantial burden of genetic and rare diseases, but access to advanced cell and gene therapies remains extremely limited. The country already possesses strong foundational assets - GenomeIndia for population-scale genomic reference data, the National Policy for Rare Diseases (NPRD) with its network of Centres of Excellence (CoEs), DBT's UMMID initiative for early diagnosis and workforce development and ICMR–DBT guidelines for safe and ethical gene therapy research. However, these efforts are currently fragmented. The GeneIndia Mission should aim to integrate these national strengths to build a seamless pathway from early detection to affordable gene and cell therapy deployment, tailored to Indian genetic diversity and health system needs.

Key Recommendations:

(i) **Expand India's Genomic Foundation**: GeneIndia should significantly strengthen the country's genomic foundation by expanding the GenomeIndia reference genome and variant frequency datasets to **50,000** and subsequently to **1 lakh individuals**, thereby enabling more precise identification of pathogenic variants across diverse

Indian populations. This expanded dataset will lay the groundwork for a robust discovery pipeline linking genomic evidence to clinical phenotypes, ultimately guiding the development of India-specific vectors, editing strategies and therapeutic constructs.

(ii) **Strengthen Early Detection through Newborn Screening:** Universal newborn screening should be progressively expanded within existing legal and ethical frameworks, building on DBT's UMMID programme and NPRD Centres of Excellence, with appropriate legislative review and safeguards. This alignment will create a seamless national pipeline that continually identifies, diagnoses and channels eligible patients into gene therapy pathways at the earliest opportunity.

(iii) **Create National Translation and Clinical Trial Platforms**: Accelerate translation from laboratory to clinic, GeneIndia should establish **3–5 national technology hubs** focused on AAV and lentiviral vector systems, non-viral delivery platforms, CRISPR and base editing technologies and RNA therapeutics. Regulatory sandboxes for first in human CGTs. These hubs should provide the IND-enabling capabilities, analytical validation and scalable vector development required to drive multiple gene therapy candidates toward clinical readiness. In parallel, select NPRD CoEs should be upgraded into Gene Therapy Clinical Units with GMP-compliant cell processing facilities, enhanced biosafety infrastructure and long-term patient monitoring systems. These upgraded centres should anchor Phase I–III clinical trials under ICMR–DBT guidelines and be supported by harmonised national registries that capture safety, durability and real-world outcomes.

(iv) **Anchor Affordable Manufacturing and Access:** To ensure long-term affordability, access and national self-reliance, GeneIndia should prioritise the establishment of regional GMP vector manufacturing hubs and a national cell therapy manufacturing centre, leveraging DBT–BIRAC's biomanufacturing framework for cost optimisation and large-scale production. Access mechanisms should be closely aligned with the NPRD's financial assistance schemes and strengthened through outcome-based procurement mechanisms led by MoHFW and NHA. Initial disease priorities should include Hemophilia A/B, SMA, β-Thalassemia, Sickle Cell Disease and key Lysosomal Storage Disorders. As a timeline, it is proposed that foundational hubs and upgraded CoEs become operational by 2027; multiple clinical trials and a national outcomes registry by 2030; India's first homegrown vector-based therapy reaches Phase III by 2033; and by 2035, two affordable, indigenous gene therapies be approved and deployed at scale across the country.

(v) **Build a Genome-to-Therapy Digital Innovation Pipeline:** Integrate computational genomics, AI-based variant annotation, digital twins of disease progression and automated vector-design platforms to power a genome-to-therapy innovation pipeline. Deploy biosensors for long-term patient monitoring post-gene therapy.

By 2035, GeneIndia should deliver a nationally integrated ecosystem and indigenous platforms for discovery, manufacturing and delivery of affordable gene cures for prevalent genetic diseases - positioning India as a global hub for affordable cell and gene therapies, while transforming access for patients with rare and genetic diseases at home.

4.1.2 AgriBio 2.0:

Envisioned as India's flagship mission to secure food systems in an era of climate volatility while improving farm profitability and ecological sustainability. The mission will leverage modern biotechnological tools, particularly CRISPR-based gene editing and the promotion of BioInputs, with a science based and transparent regulatory framework which ensures biosafety, public confidence and compliance with national and international standards. This mission's core anticipated outcome by 2035 is the development and

deployment of a range of climate - resilient crops exhibiting enhanced tolerance to abiotic stresses such as drought, heat and salinity, alongside the widespread adoption of effective and environmentally friendly biofertilizers and biopesticides thus, protecting soil health, minimizing adverse ecological impacts and safeguarding human, animal and environmental health along with ensuring equitable access to farmers.

Key Recommendations:

(i) **Converge National Agriculture and Biotechnology Programmes:** The Mission is not intended to create parallel programmes, but to integrate and amplify existing national agriculture and sustainability initiatives, accelerating the translation of scientific breakthroughs into field-level impact at scale.

AgriBio 2.0 should be built upon and integrate several existing national programs aimed at making Indian agriculture both profitable and environmentally sustainable, while accelerating the deployment of next-generation biotechnologies.

India already has a strong foundation through initiatives such as the National Mission on Sustainable Agriculture (NMSA), Paramparagat Krishi Vikas Yojana (PKVY) for organic farming, Mission for Integrated Development of Horticulture, National Food Security Mission and the Soil Health Card Scheme, which collectively promote efficient nutrient management, climate-resilient farming practices, water-use efficiency and reduced chemical dependence. Additionally, DBT's own flagship efforts - such as the Biotech-KISAN programme, Biotech Krishi Innovation Science Applications Network, Farmer Resource Groups (FRGs), Biofuel and Bioenergy Mission and support for Biofertilizer and Biopesticide Quality Control Labs - provide a proven translational ecosystem for farmer-centric innovation and technology adoption. Building on these platforms, *AgriBio 2.0* must leverage advanced biotechnological tools - particularly CRISPR-based gene editing, genomic selection and molecular breeding—to develop and deploy a new generation of climate-resilient crop varieties with improved tolerance to drought, heat, salinity and emerging pests.

(ii) **Accelerate Development of High-Quality Bio-Inputs:** The Mission should promote the widespread adoption of high-quality bioinputs, including biofertilizers, biopesticides, microbial consortia and soil health enhancers, aligned with the national goals of reducing chemical fertilizer usage under the Bharat Krishi Initiative and Sustainable Agriculture Mission. Field-testing, validation and farmer-scale demonstrations of these innovations will be undertaken through the Biotech-KISAN hubs, Krishi Vigyan Kendras (KVKs) and state agricultural universities, ensuring seamless transfer of improved crop varieties and bioinputs to farming communities. This quality-first sequencing protects farmer trust and directly serves national goals of reducing chemical fertilizer dependence.

(iii) **Establish BioInput Production and Innovation Clusters:** To ensure affordability, accessibility and environmental stewardship, the AgriBio 2.0 should establish a network of BioInput Production and Innovation Clusters - co-located with existing DBT-supported rural biotechnology hubs - to scale up indigenous production of biofertilizers, biostimulants, biopesticides and microbial seed coatings. These efforts will be further supported by convergence with the PM PRANAM Scheme (for reducing chemical fertilizer dependence), Atmanirbhar Clean Plant Initiative and state-level organic and natural farming missions.

By 2035, AgriBio 2.0 should aim to deliver commercially deployable climate-resilient crop varieties, ensure the mainstreaming of environmentally friendly bioinputs across major cropping systems and position India as a global leader in sustainable biotechnologies that enhance farm profitability while safeguarding ecological health and farmer interest.

4.1.3 **BioX Foundry:**

This is proposed as a core component of India's BioE3 Policy, building directly upon the emerging DBT National Biofoundry Network, Bio-AI Hubs and Biomanufacturing Hubs. These platforms, highlighted in DBT's approved Implementation Plan for High-Performance Biomanufacturing, provide the foundation for establishing fully automated Design–Build–Test–Learn (DBTL) innovation cycles essential for modern synthetic biology and metabolic engineering. The BioX Foundry mission aims to operationalize and scale these DBTL systems across a distributed network of national hubs, enabling India to move from a research-centric biotechnology ecosystem toward a globally competitive biomanufacturing hub. The Biofoundries also provide wide access to innovators, academia and startups to scale their bio-based innovative products to pre-commercial scales without IP as a service.

Key Recommendations:

(i) Build World-Class DBTL platforms for product innovation. BioX Foundry should drive India's synthetic biology capability to the next level by supporting the development across:

- Novel biomaterials
- High-value biochemicals
- Sustainable industrial enzymes
- Smart proteins
- Next-generation biopharmaceuticals.

The mission envisions that, by 2035, these DBTL platforms, supported by AI-driven predictive design tools and advanced laboratory automation, will collectively enable the incubation, growth and scale-up of at least **100 high-potential SynBio startups**. These enterprises will be empowered to rapidly prototype and validate bio-based products, transition into pilot and pre-commercial scale production and enter regulated markets with technical, regulatory and infrastructure support from the Biofoundry and Biomanufacturing Hub ecosystem.

(ii) Strengthen the continuum from innovation to scale-up by tightly integrating Biofoundries with next-generation Bio-AI Hubs to accelerate the DBTL cycle. This connected architecture spanning design to deployment will sharply reduce the time, cost and risk of scaling bio-based products, while creating shared national infrastructure that can be accessed by startups, academic groups and industry alike.

(iii) Anchor Global Manufacturing Leadership and Talent Development: aligned with the vision articulated in the BioE3 Policy and the National Bioeconomy Roadmap, BioX Foundry should be positioned to play a pivotal role in transforming India into a trusted global supplier of high-performance biomanufactured products. BioX Foundry must be built around robotic automation, AI-native DBTL cycles, biosensor-embedded bioprocessing and computational metabolic modelling, creating a national platform for autonomous synthetic biology innovation.

(iv) Priority actions include strengthening domestic supply chains, mobilising public–private partnerships, developing specialised talent in automation and computational biology and positioning India as a preferred destination for contract biomanufacturing and fermentation-based production.

By 2035, BioX Foundry Mission should help establish a globally recognized ecosystem capable of delivering sustainable, affordable and competitive bio-based innovations that advance India's economic, industrial and strategic interests. BioX Foundry must be built around robotic automation, AI-native DBTL cycles, biosensor-embedded bioprocessing and computational metabolic modelling, creating a national platform for autonomous synthetic biology innovation.

4.1.4 One Health Grid:

Recognising the interconnectedness of human, animal and environmental health, the One Health Grid mission prioritises the establishment of a robust surveillance network and enhanced capabilities for zoonotic disease prediction, prevention and response, alongside strengthening biosecurity measures. The primary anticipated outcome by 2035 is a significantly strengthened national surveillance system capable of early detection and rapid response to emerging infectious diseases and biological threats.

Key Recommendations:

(i) **Anchor the Grid within the National One Health Mission:** It is proposed that the *One Health Grid* mission be positioned as a core operational pillar within the National One Health Mission (NOHM), leveraging India's emerging whole-of-government architecture that integrates human, animal, environmental and wildlife health systems. As highlighted during the National One Health Mission Assembly 2025, India has already begun implementing integrated surveillance across slaughterhouses, bird sanctuaries, zoos and wastewater facilities for tracking pathogens and antimicrobial resistance, alongside joint outbreak investigations and medical countermeasure development.

The One Health Grid mission will build upon these initiatives by establishing a digitally connected, interoperable national surveillance network capable of early detection, risk assessment and rapid response to zoonotic and climate-linked threats. This Grid will incorporate real-time data streams from IDSP/IHIP, Bharat Pashudhan, VRDL networks, environmental monitoring systems and wildlife health platforms, enabling evidence-driven outbreak anticipation and biosecurity action across sectors.

(ii) **Strengthen High-Containment and Rapid-Response Capacity:** To drive operational readiness, it is proposed that the One Health Grid integrate and strengthen the 23 BSL-3/4 laboratories established under NOHM, while expanding their linkages to state disease diagnostic labs, veterinary labs, forest department networks and environmental health laboratories. These high-containment facilities recognized as India's first line of defense will be embedded into a hub-and-spoke model reaching district-level rapid response units, supported by National Joint Outbreak Response Teams (NJORT), Public Health Emergency Operation Centres (PHEOCs) and joint SOPs for coordinated action.

(iii) **Deploy Biosensor Networks:** Establish nationwide biosensor network across livestock farms, water bodies, slaughterhouses and wastewater systems for real-time pathogen detection and predictive outbreak analytics.

(iv) **Integrate Research, Genomics and Medical Countermeasures:** Ongoing ICMR-led initiatives such as multi-sectoral syndromic surveillance, hospital wastewater AMR monitoring, bird sanctuary surveillance and pathogen discovery programmes will be integrated into the Grid's real-time dashboard, which already hosts initiatives from states, central departments and multilaterals.

DBT's role will be central through its support for genomic platforms, CRISPR-based diagnostics, AMR surveillance innovations and the emerging National Biofoundry Network, which can provide rapid design–build–test capability for medical countermeasures, environmental biosensors and pathogen detection kits. ICMR will anchor harmonised laboratory protocols, multiplex diagnostic networks and medical countermeasure R&D, while NCDC will integrate human health surveillance under IDSP/IHIP, develop risk maps and coordinate joint outbreak investigations. The One Health Grid mission will additionally harness community-level reporting through ASHAs, Pashu Sakhis and forest frontline staff, an approach recommended during the NOHM State–UT workshop for improving early warning and ground-level intelligence.

By 2035, the proposed One Health Grid should aim to deliver a unified, technology-enabled national early warning system with predictive analytics, AI-assisted risk scoring and cross-border outbreak intelligence. This will result in a significantly strengthened national biosecurity architecture capable of rapid detection and response to emerging infectious diseases, zoonotic spillovers, AMR hotspots and environmental health threats. Through coordinated engagement of MoHFW, DBT, ICMR, ICAR, MoEFCC, DAHD, NCDC and state governments, the Grid must support India's long-term goal of achieving *One Earth, One Health, One Future* while transforming the nation into a global leader in integrated pandemic preparedness and multisectoral health security.

4.1.5 **Marine Biotechnology:**

This mission aims to harness the vast potential of India's marine resources through advancements in marine biotechnology and algae- based technologies to drive innovation in areas such as marine bioproducts, nutraceuticals and bioenergy derived from algae. By 2035, the Mission should aim to deliver a substantial expansion in marine-derived exports, anchor large-scale seaweed cultivation and catalyse vibrant coastal bioeconomies positioning India as a leading player in sustainable ocean-based industries.

Key Recommendations:

(i) **Anchor the Mission within the National Blue Economy Framework:** The Marine Biotechnology Mission should be positioned as a strategic pillar of the National Blue Economy Policy, building on MoES-led initiatives, PMMSY seaweed interventions and expanding R&D efforts. India's coastline and EEZ offer substantial potential for marine bioresources and the Blue Economy framework emphasizes sustainability, innovation and livelihood generation as core imperatives.

(ii) **Scale Seaweed Cultivation as a Flagship Opportunity:** A foundational opportunity lies in scaling seaweed cultivation, which is already supported under PMMSY with **₹640 crore** allocated for infrastructure and support, enabling establishment of a seaweed park in Tamil Nadu, a brood bank in Daman & Diu and approval of over 46,000 rafts and 65,330 tubenets for farmers.

Seaweed cultivation requires no land, freshwater, fertilisers or pesticides, making it inherently sustainable and climate-positive. India hosts 844 seaweed species, of which around 60 are commercially valuable, creating large potential for biomaterials, phycocolloids (alginate, agar, carrageenan), nutraceuticals and biostimulants. Seaweed-derived biostimulants are already recognised under the Fertilizer (Control) Order, enabling faster translation into agri-bioinput markets.

Integrating computational marine biology, biosensors for ocean-health monitoring and AI-based aquaculture optimization will enhance yield forecasting, species protection and blue-economy resilience.

(iii) **Accelerate R&D–Industry Translation and Coastal Livelihoods:** The Marine Biotechnology Mission should focus on R&D–industry translation, biorefinery development, value-added marine bioproducts and sustainable coastal livelihoods. The EY Blue Economy report emphasises marine biotechnology as one of India's highest-potential innovation sectors, supported by DBT's BioE3 Policy and Deep Ocean Mission bioprospecting initiatives. It also highlights the surge in investor interest, advanced ocean data systems, sustainable aquaculture and marine biotech as emerging growth pillars. Aligning the Mission with these national priorities strengthens India's leadership in sustainable ocean resource utilization.

(iv) **Create Integrated Marine Bioresource Hubs:** The Mission should establish integrated marine bioresource hubs, leveraging MoES ocean observation systems, NCCR's coastal research capabilities, DBT's bioprocessing and synthetic biology platforms

and ICAR–CMFRI's seaweed and mariculture expertise. The Mission should prioritise high-value product pipelines - nutraceuticals, marine enzymes, biopolymers, phycocolloids, specialty chemicals and algae-based bioenergy—supported by pilot-scale biorefineries. The Community-led models highlighted in national case studies, such as Odisha's women-led seaweed farming, demonstrate scalable livelihood impacts and a blueprint for social inclusion.

By 2035, the Mission should aim to significantly expand India's marine-derived exports, unlock large-scale seaweed farming as announced in national budget priorities, stimulate coastal bioeconomies and develop globally competitive marine bioproduct industries. This will contribute directly to the country's vision of a **$100-billion** blue economy and Viksit Bharat 2047, while ensuring sustainability and resilience as emphasized in the Blue Economy policy narrative.

4.1.6 BioPharmaNext:

BioPharmaNext aims to position India as a global hub for next-generation biopharmaceuticals by 2035. Building on India's demonstrated leadership in vaccines and biosimilars and anchored by the foundational investments of Biopharma SHAKTI announced in the Union Budget (2026-2027). This mission will scale affordable biologics, advance monoclonal antibodies and integrate AI-driven drug discovery with cutting-edge manufacturing platforms, including emerging cell and gene therapy segments.

Anchored by DBT, DoP, MOHFW and CDSCO, BioPharmaNext will strengthen regulatory science, clinical research capacity and global partnerships to ensure that advanced therapies are not only innovative but also accessible. The mission complements GeneIndia which focuses on curative frontier therapies by anchoring scale, affordability and global supply in mainstream biologics.

Key Recommendations:

(i) **Establish India as a Global Biopharmaceutical Hub by 2035:** Building directly on the economic opportunity, BioPharmaNext must capture India's rare window to lead global value chains in biosimilars, monoclonal antibodies, advanced biologics, drug conjugates and AI-driven biologic innovation:

- Biosimilars are projected to grow at **17% CAGR** with nearly **10x ROI**, contrasting sharply with stagnating generics markets growing at just 2%.
- **By 2035, 40% of all global medicines** are expected to be biologics and **$300 billion** worth of blockbuster biopharmaceuticals will go off-patent by 2030 creating a historic window for India to enter global value chains.
- Even a 1 % share in the global biosimilar market (estimated between $73 billion & $76 billion) by 2030 could generate roughly **₹6400** crore annually by **2030.** Similarly, increasing India's presence in the global patented biologics market presents a significant opportunity for additional high-value revenues, innovation and exports.

BioPharmaNext should build on the **₹10,000 crore Biopharma SHAKTI** outlay and the network of **3 new National Institutes of Pharmaceutical Education and Research** to drive this commercial ambition with institutional depth.

(ii) **Build AI-Enabled Discovery and Development Platforms:** BioPharmaNext must integrate transformative digital technologies to transition Indian pharma from a generics model to an innovation-led one. BioAI for closed experimental models designing novel biomolecules, enzymes and medicines.

- Deploy AI-driven drug discovery, large-scale genomics, BioDigital Twins and automated Design-Build-Test-Learn (DBTL) engines capable of **reducing drug development timelines by 60–80%, lowering R&D costs by 20–30%** and improving clinical trial success rates.

- Leverage India's genetically diverse population as a strategic asset for AI-powered trial design and drug repurposing at scale.
- Establish platform-based discovery engines that can design, optimize and repurpose biologics rapidly. Global case studies show AI-designed drugs **reaching Phase 1 in under 30 months,** India must match this cadence.
- Complement AI-driven discovery with automated robotics for high-throughput protein engineering, biosensor-driven quality control systems and national bio-compute infrastructure.

By 2035, these platforms should enable India to originate, not merely replicate, next-generation biologics.

(iii) **Remove Structural Bottlenecks:** To unlock the full potential of BioPharmaNext, systemic barriers must be addressed decisively. Key bottlenecks that require urgent resolution include:

- Regulatory timelines that currently average 900 days, compared to 500 days in peer countries, a gap that directly impairs India's global competitiveness.
- Fragmented multi-agency approval processes that increase uncertainty and delay for innovators and manufacturers alike.
- Limited clinical trial capacity exacerbated despite India's scale advantage requiring urgent infrastructure and institutional investment. The Biopharma SHAKTI initiative to create a network of over 1,000 accredited India Clinical Trials sites provides a vital foundation.
- Underdeveloped High-Performance Computing (HPC) infrastructure, which constrains AI-enabled discovery and in-silico trial capabilities.
- Persistent shortages in advanced biopharma talent, including computational biologists, regulatory scientists and advanced manufacturing specialists.

(iv) **Establish National Infrastructure and Fast-Track Pathways:** The following mission components are essential to realising BioPharmaNext's 2035 ambitions:

- **Exclusive Regulatory Sandbox -** Create a dedicated, time-bound regulatory pathway for:
  - Biosimilars and novel biologics
  - Cell/gene-adjacent biologics and CRISPR therapeutics
  - Synthetic biology products and AI-designed drugs

This sandbox should operate with pre-set approval timelines, expert multi-agency panels and transparent milestone reviews to reduce uncertainty while maintaining rigour.

- **Five Integrated Bioinnovation Clusters -** Establish a minimum of five Bioinnovation clusters anchored around public research institutions in PPP mode building on the Regional Medical Hubs model proposed in Budget 2026–27 with:
  - Integrated bioprocessing and clinical-grade manufacturing
  - GLP/GMP facilities accessible to SMEs and startups
  - Startup scale-up infrastructure and shared services
- **High Performance Computing Capability Centres -** Establish HPC Capability Centres under the National Supercomputing Mission, comparable to EU and Chinese capabilities, for:
  - AI-enabled drug discovery and molecular simulation
  - In-silico clinical trials and biomarker modelling
  - National Bioinformatics Data Infrastructure

- **BioTalent Strategic Network** - Build a national talent pipeline through:
  - India-wide training programmes in computational biopharma
  - Expanded grants for AI-enabled drug discovery research
  - Enhanced re-entry fellowships for Indian diaspora scientists
  - Integration with the **100,000 Allied Health Professionals** pipeline announced under Biopharma SHAKTI
- **Market Access Reforms** - Introduce a Made-in-India Innovation Track that includes:
  - 180-day listing pathway for domestic biologics
  - IPO flexibility for pre-revenue biopharma firms
  - Government procurement preferences for Indian-manufactured biologics

By 2035, BioPharmaNext should deliver the following outcomes:

BioPharmaNext	GeneIndia (Complementary Mission)
Monoclonal antibodies	Gene therapies
Next-gen biosimilars	Cell therapies
Long-acting biologics	CRISPR / curative platforms
AI-designed therapeutics	Rare disease therapies
Global biosimilar supply	Frontier R&D

Together, BioPharmaNext and GeneIndia will deliver India's twin biopharmaceutical vision: a trusted global supplier of affordable biologics for mainstream markets and a frontier innovator in curative therapies advancing both Atmanirbhar Bharat and Viksit Bharat 2047.

4.2 Set up Empowered Committees on National BioMissions

Biotech presently does not have empowered committees and it is critical to establish such committees to ensure National BioMissions are successfully implemented. These high-level committees to be established will have cross-ministerial representations to ensure mission governance, align public-private investments, augmented with efficient regulatory system changes in real time.

4.2.1 Empowered Committee on National BioMissions:

This committee will coordinate inter-ministerial strategies, set national priorities and align budgets for the effective execution of BioMissions.

It will act as a single-point decision-making body to reduce fragmentation across ministries and ensure faster approvals and implementation. The committee should also establish clear performance metrics and review mechanisms to track mission outcomes. In addition, it can facilitate course corrections and policy alignment based on evolving technological and market dynamics.

4.2.2 National BioData Council:

This council will govern the digital infrastructure, facilitate secure data sharing and create standards for data interoperability to support AI-driven biotech innovation. This council should also anchor India's National Computational Biology Grid, integrating high-performance GPUs, multi-omics data engines and digital repositories essential for CGTs, genomics and synthetic biology.

It will play a critical role in ensuring data sovereignty, privacy, and ethical use of biological data while enabling innovation. The council can also promote public-private data partnerships to unlock high-value datasets for research and commercialization. Further, it should enable real-time analytics and decision support systems for healthcare, agriculture, and environmental applications.

4.2.3 **BioEconomy Investment & Policy Forum:**

This forum will bridge government, industry, VCs and research institutions to align investments with national BioEconomy goals, de-risk early-stage biotech investments, promote PPPs and support scale-up efforts.

It can serve as a strategic platform for mobilizing domestic and global capital, including sovereign funds and impact investors. The forum should also identify priority sectors and investment gaps, guiding targeted funding interventions. Additionally, it can facilitate policy dialogue and regulatory clarity to improve ease of doing business in biotechnology.

4.2.4 **BioIP & Innovation Evaluation Agency:**

This agency will assess the value of IP, support startups in patenting and licensing and conduct due diligence for commercialization.

It will help build standardized frameworks for IP valuation, enabling better access to funding and partnerships. The agency can also provide handholding support to startups and research institutions in navigating global IP regimes. Further, it can strengthen India's position by promoting technology transfer, licensing strategies, and global IP competitiveness.

4.3 Establish a ₹50,000 Crore ($5.8 Billion) BioEconomy Growth Fund (2026–2035)

4.3.1 **Catalyse Scale-up Financing for Biotechnology:** India today very much requires biotech investment support, especially with startups who have established Proof of Concept and have challenges related to funding for scale-up and commercialisation. This dedicated fund, apart from BioE3 policy including those under ANRF, can ensure long-term scale-up for promising entrepreneurs, offering viability gap financing, equity-risk instruments and milestone-based grants. This is specially for mid-to-late-stage ventures and BioManufacturing infrastructure. This will ensure our ambition to make India as a global innovation and manufacturing hub will be achieved.

4.3.2 **Introduce a Production-Linked Incentive for Biomanufacturing:** India's ProductionLinked Incentive (PLI) framework has already demonstrated its effectiveness in scaling complex manufacturing in closely adjacent biosectors, notably pharmaceuticals, bulk drugs and medical devices, where it has driven significant investment, reduced import dependence and expanded exportoriented capacity. Building on this experience, a dedicated PLI for biomanufacturing covering areas such as fermentationbased products, advanced biologics, biosimilars, enzymes and biobased intermediates would support scaleup, cost competitiveness and domestic value creation. Anchored in output-linked incentives and aligned with existing pharma and medicaldevice PLIs, such an intervention would help translate India's scientific strengths into globally competitive manufacturing while strengthening supplychain resilience and strategic autonomy.

4.3.3 **Anchor Biotechnology Financing within the RDI Scheme:**

(i) The newly launched **₹1 lakh crore RDI Scheme** - designed to catalyse private-sector R&D through long-term, low-interest financing and Deep-Tech Fund-of-Funds - provides a powerful national framework into which a dedicated BioEconomy Growth Fund can be embedded. Since biotechnology, biomanufacturing, synthetic biology, pharma and medical devices are among the priority sunrise sectors explicitly identified by the RDI Scheme, integrating a sector-focused Special Purpose Fund

(SPF) aligns fully with the Scheme's mandate of accelerating innovation, reducing import dependence and strengthening India's strategic capabilities.

(ii) It is therefore proposed that the Government establish a **₹50,000 Crore ($5.8 Billion) BioEconomy Growth Fund (2026–2035)** as a Special Purpose Fund under ANRF/RDI, dedicated to catapulting India's bioeconomy. The RDI Scheme already envisions unsecured long-term financing, refinancing, equity-risk instruments and contributions to Deep-Tech Funds-of-Funds for private sector R&D and commercialization. The proposed BioEconomy Growth Fund would operationalize this vision specifically for the biotechnology ecosystem, enabling India to convert its research strengths into globally competitive biomanufacturing, affordable biologics, bio-based materials, health technologies and synthetic biology products.

(iii) The fund would focus on mid- and late-stage biotech ventures, which the RDI Scheme identifies as the most financially constrained - particularly those requiring scale-up infrastructure, GMP manufacturing, biofoundries, regulatory readiness and commercial. Support mechanisms could include viability gap financing, blended finance, milestone-based grants, catalytic equity and infrastructure financing to accelerate projects across biomanufacturing, advanced therapeutics, precision fermentation, biomaterials, diagnostics, medtech and synthetic biology-areas highlighted as national priorities. This directly complements the BioE3 Policy's vision of biomanufacturing and biofoundry networks and fills the gap between prototype development and commercial-scale production.

(iv) A BioEconomy SPF would also strengthen India's transition from a generics-driven industry to a high-value innovation ecosystem, addressing vulnerabilities exposed during COVID-19 and aligning with India's strategic priorities across health security, climate action, sustainable industries and Atmanirbhar Bharat.

By establishing a long-term, predictable funding mechanism for biotechnology-led innovation and manufacturing, India can translate its scientific capabilities into global market leadership, enabling the creation of new industries, exports and high-value jobs. A **₹50,000 crore BioEconomy Growth Fund within the RDI Scheme** would therefore be a strategic and timely intervention to realize India's ambition of becoming a **$691+ billion bioeconomy** and a global biomanufacturing hub by 2035.

4.4 Reform the Biotech Regulatory Landscape with Differentiated Pathways

India's biotechnology sector cannot sustain its next phase of growth without urgent and structural regulatory reforms. The current framework, characterized by fragmentation, multi-agency overlaps, and prolonged approval timelines, is increasingly misaligned with the pace of innovation in areas such as biologics, synthetic biology, and AI-driven solutions. There is an immediate need to establish differentiated, time-bound, and risk-based regulatory pathways that enable faster translation from lab to market. A bold, coordinated reform agenda is essential to unlock innovation, attract global investments, and position India as a competitive biotechnology powerhouse.

4.4.1 **Establish a Regulatory Sandbox -** immediately while the overall reforms are taken up. This Sandbox will serve as a test-bed for near-to-market innovative solutions to have faster approval.

4.4.2 **Revitalize India's biotech regulatory framework -** (CDSCO, RCGM, GEAC, FSSAI, NBA) to overcome delays and bureaucratic hurdles (involvement of multiple departments in the approval process which needs to be fine-tuned) in the current regulatory system, including persistent bottlenecks (related to environmental clearances at the state level and layers of communication).

(i) Establish new regulatory frameworks led by AI-designed for biologics, automated robotic biomanufacturing, biosensor-based diagnostics and machine led computation of evidence used in clinical submissions.

(ii) Establish a dedicated Regulatory Reform Task Force with Industry Associations, Academia, Government agencies and experts.

- To streamline pharmaceutical and biotechnology regulations with clear, time-bound pathways for advanced therapies, novel biologics, biosimilars, CRISPR-based therapeutics synthetic biology and microbiome products.
- Time-bound approval pathways for emerging modalities to boost investor confidence and accelerate commercialization of innovations.

4.4.3 **Modernize and upgrade CDSCO -** by adopting global best practices beyond digitization. This includes integrating benefit–risk monitoring across the drug lifecycle, leveraging real-world evidence and decentralized trial models, adopting non-animal testing methodologies (NAMs), strengthening GMP compliance with advanced data integrity frameworks, and aligning with ICH/PIC/S standards. These measures based on best practices in CDSCO operations for delivering timely approvals will not only build investor confidence and promote global competitiveness but will also enable taking regulatory decisions that continue to serve the best interests of public health in India and to be at par with global bodies such as FDA, EMA, and PMDA.

4.4.4 **Patent Law Updates for Biotech -** this includes bringing greater clarity on Section 3 exclusions for biotech inventions (specifically imported microbes and GM microbes in the agriculture segment), establishing a National Bio-IP Repository and tokenizing innovations for market-linked valuation (IP-backed financing).

4.5 Creating Bioscience leaders through strengthening public institutions network in Biotech

4.5.1 India's biotech sector employs over **3.3 million professionals** and nearly **12,000 startups.** Yet with only **~259 researchers per million** people and just **25.6%** of higher education enrolment in STEM (450,000 students and researchers are pursuing biotech studies), the talent pipeline remains thin. To stay competitive, India must strengthen undergraduate biotech programs, increase number of biotech specific merit scholarships & fellowships matching to international standards, and build frontier skills in bioinformatics, AI-driven biotech, and advanced biomanufacturing.

4.5.2 Strengthening of research training programs like PhDs and Post-doc would build a robust indigenous talent pool for the ambitious target set for the Bioeconomy.

4.5.3 Experiential learning–immersion training for Master's and PhD students coalescing technical and hands-on experimental learning with real-world experiences/grass root engagement fostering personal growth and deepening critical-thinking, problem-solving and collaborations.

4.5.4 Enhancing fellowships for research training, facilitating Post-doc entrepreneurship programs must be facilitated for nurturing our youth and enable them to contribute to Viksit Bharat goals through Biotechnology R&D contributing to green growth and shared prosperity.

4.5.5 Strengthen biotech talent through industry-aligned, multidisciplinary training in biology, AI, bioinformatics, regulatory sciences, and biomanufacturing.

4.5.6 Strengthen the biotech entrepreneurship ecosystem by enhancing incubation, mentorship, funding access, commercialization support, and industry partnerships.

5. THE COST OF INACTION

Any delay or hesitation in acting on the key recommendations, carries a clear cost of inaction. It would slow India's progress in consolidating its bioeconomy capabilities at a time when global competitors are moving decisively to scale innovation and manufacturing. Such delays risk erosion of first-mover advantages and continued dependence on external supply chains. Inaction will also lead to loss of investment, talent and market opportunities, to other countries that are advancing more rapidly in this space.

Given that biotechnology is a high-tech, innovation-driven domain with long gestation periods for R&D, commercialization and regulatory approvals, lost ground will be difficult to regain.

With timely policy action, adequate funding and strategic support, India is well-positioned to deliver high-quality, globally competitive bioproducts, at cost-effective scales — particularly suited for emerging and developing markets.

It is therefore, imperative to act now to sustain momentum and secure India's leadership in the global BioEconomy.

What Is at Stake?

Failure to move decisively would impose costs across six national dimensions:

i. **Missed Economic Opportunity:** Failure to capitalise on the fastest-growing deep-tech industrial domain **(10-12% global CAGR)**.
ii. **Concern on National Security:** Increased reliance on other nations for critical biological solutions (e.g., vaccines, therapeutics, food, biodefense).
iii. **Challenges in reaching the Viksit Bharat Goals:** A significant impediment to achieving the **$30 trillion** economy target and associated job creation.
iv. **Loss of Global Leadership:** India forfeiting its potential to lead in an era defined by biological mastery.
v. **Environmental Setbacks:** Slower adoption of green industrial transformation (specifically to BioIndustrial segment) and climate-resilient solutions (specifically to BioAgriculture segment).
vi. **Loss of employment generation:** The biotech segments long-term growth projections have opportunity to create **30-35 million jobs.**

India now stands at the threshold of shaping the biological century, with an opportunity that goes far beyond economic expansion. By executing this roadmap with ambition and urgency, India can build a new paradigm of development where biology powers industry, sustainability, and human well-being at scale. The gains are transformative: a multi-trillion-dollar bioeconomy, millions of high-quality jobs, resilient health and food systems and leadership in climate-positive technologies. India can evolve from being the "pharmacy of the world" to the "Innovation Engine of the World", delivering not just affordable solutions, but frontier breakthroughs that redefine global benchmarks. This is a moment to convert scientific capability into civilizational impact where India shapes markets, standards, and solutions for itself and the world.

What makes this vision achievable is India's rare convergence of science, scale, and demographic purpose. Few nations possess the combination of deep public research institutions, globally competitive manufacturing, digital public infrastructure, biodiversity wealth and a vibrant startup ecosystem. India has already demonstrated its ability to deliver at scale under pressure from vaccines to digital platforms and now could extend that capability into the frontier domains of biotechnology. With BioE3 as the strategic compass and mission-mode execution as the engine, India can leapfrog traditional pathways and define a uniquely inclusive and sustainable model of bioeconomic growth. The next 10 years is not just about catching up; it is about leading with conviction and clarity to emerge as the world's BioCapital.

The biological century will be shaped by those who act now and fast. India has the capability and this is the moment to lead.

Annexures

Glossary of Key & Technical Terms

This annex provides definitions of technical and policy-relevant terms appearing in the BioEconomy Roadmap. The glossary is organised alphabetically and written in plain language for easy understanding.

Terms	Definition (Plain Language)
ADME/Tox	Framework to evaluate how a drug is absorbed, metabolised and tested for toxicity.
AgriBio 2.0	Proposed mission focused on climate-resilient agriculture and bioinputs.
AI–Bioinformatics Platforms	AI systems that analyze biological and genomic data.
Alternative Proteins	Non-animal protein sources such as plant, microbial and cultivated protein.
Bio+X Convergence	Blending biotechnology with digital, quantum and materials technologies.
BioAI	Using artificial intelligence to accelerate biological discovery and health innovation.
BioDigital Twins	Digital models that simulate biological systems for prediction and testing.
BioEconomy Growth Fund	Proposed national vehicle for financing bioeconomy ventures.
BioE3 Policy	Biotechnology for Economy, Environment and Employment policy document brought out by Department of Biotechnology, Government of India for fostering High-Performance Biomanufacturing.
BioFoundry	Automated lab enabling rapid biological engineering cycles.
Biofuel and Bioenergy Mission	Focuses on transforming agricultural and industrial waste into clean, renewable energy.
BioIndustrial	Use of biotechnology in materials, chemicals and manufacturing.
BioPharmaNext	Proposed mission focused on advanced biologics and next-generation therapies.
BioRegulatory Authority	Proposed centralized biosciences regulatory framework.
Biotech-KISAN	Krishi Innovation Science Application Network connects agricultural scientists with small, marginal, and women farmers.
BioTranslation Grid	Ecosystem designed to move research towards commercialization.
CAPA	Corrective and Preventive Action framework for quality assurance.
Cell & Gene Therapies	Treatments that modify cells or genes to address disease.
Continuous Bioprocessing	Ongoing automated production of biologics.
CRDMO	Contract organizations supporting R&D and manufacturing.
CRISPR	Precision genome editing tool.
DBTL	Design-Build-Test-Learn engineering approach.

Terms	Definition (Plain Language)
Decentralised Clinical Trials	Clinical studies conducted partially outside hospitals using digital tools.
Digital Batch Records	Electronic tracking of manufacturing processes.
Engineered Living Materials	Materials embedded with biological functions.
Empowered Committee on BioMissions	National governance mechanism proposed for mission execution.
Federated Real-World Evidence	Use of distributed clinical data for research without central storage.
GeneIndia	Proposed mission to expand gene therapy access.
GMP	Good Manufacturing Practice standards.
HPC Capability Centres	High-performance computing hubs for biotech research.
HPAPI	Highly potent pharmaceutical ingredients.
In-Silico Trials	Computer-simulated testing replacing parts of clinical trials.
Input–Output Modelling	Economic analysis technique for bioeconomy valuation.
LNP	Lipid nanoparticles used to deliver genetic material.
Marine & Blue Biotechnology	Biotech-based on marine organisms and resources.
Master Protocols	Unified frameworks testing multiple drugs in one trial.
MIDH	Mission for Integrated Development of Horticulture (MIDH) promotes holistic growth of the horticulture sector. It provides technical and financial assistance for the production of quality planting materials, area expansion, post-harvest management, and skill development.
National BioData Infrastructure	Framework for secure biological data sharing.
National Blue Economy Policy	Aims to use ocean and coastal resources to grow the economy ” in the Glossary of Key & Technical Terms Section.
NFSM	National Food Security & Nutrition Mission aims to boost food grain production through area expansion and higher productivity while restoring soil fertility.
NMSA	The National Mission for Sustainable Agriculture (NMSA) promotes climate-resilient farming by optimizing water use efficiency, enhancing soil health, and supporting diversified integrated farming systems.
Neuro-Symbolic AI	Hybrid AI combining learning with logical rules.
One Health Grid	Integrated surveillance across human, animal and environmental health.
Planetary Bioengineering	Large-scale use of biotech for environmental restoration.
Precision Fermentation	Production of targeted molecules via engineered microbes.
PMKVY	Paramparagat Krishi Vikas Yojana (PKVY) has provided farmers with an organised platform to adopt eco-friendly practices, access organic certification, and link with markets that reward sustainable production.

Terms	Definition (Plain Language)
PPP	Public–Private Partnership.
QSP	Quantitative Systems Pharmacology modelling.
Quantum Biology	Study of quantum effects in living systems.
Real-World Evidence Engines	Systems capturing real-life health outcomes.
Regulatory Sandbox	Controlled testing environment for innovations.
Synthetic Biology	Engineering of biological systems.
Smart Quality Systems	AI-enabled quality monitoring.
Triangulation Model	Three-part method to estimate bioeconomy value.
Translational Infrastructure	Facilities moving research to market.
Viability Gap Funding	Government support to make critical projects feasible.

List of Abbreviations

Abbreviation	Meaning
AAV	Adeno-Associated Virus
AMR	Antimicrobial Resistance
ANRF	Anusandhan National Research Foundation
API	Application Programming Interface
BIRAC	Biotechnology Industry Research Assistance Council
CAGR	Compound Annual Growth Rate
CAPA	Corrective and Preventive Action
Cap Ex.	Capital Expenditure
CDMO	Contract Development and Manufacturing Organization
CDSCO	Central Drugs Standard Control Organisation
CGT	Cell and Gene Therapy
CMFRI	Central Marine Fisheries Research Institute
CoE	Centre of Excellence
CRO	Contract Research Organization
CRDMO	Contract Research, Development and Manufacturing Organisation
CRISPR	Clustered Regularly Interspaced Short Palindromic Repeats
CSIR	Council of Scientific and Industrial Research
DBT	Department of Biotechnology
DBTL	Design–Build–Test–Learn
DOP	Department of Pharmaceuticals
EMA	European Medicines Agency
EEZ	Exclusive Economic Zone
FAO	Food and Agriculture Organization
FDA	Food and Drug Administration
FSSAI	Food Safety and Standards Authority of India
GLP	Good Laboratory Practice
GM	Genetically Modified
GMP	Good Manufacturing Practice
GPU	Graphics Processing Unit
ICAR	Indian Council of Agricultural Research
ICMR	Indian Council of Medical Research
IHIP	Integrated Health Information Platform

Abbreviation	Meaning
IND	Investigational New Drug
IP	Intellectual Property
LNP	Lipid Nanoparticle
MoA&FW	Ministry of Agriculture & Farmers Welfare
MoEFCC	Ministry of Environment, Forest and Climate Change
MoES	Ministry of Earth Sciences
MoHFW	Ministry of Health & Family Welfare
NBA	National Biodiversity Authority
NBDS	National Biotechnology Development Strategy
NCDC	National Centre for Disease Control
NHA	National Health Authority
NOHM	National One Health Mission
NPRD	National Policy for Rare Diseases
OECD	Organization for Economic Co-operation and Development
PLI	Production Linked Incentive
PMDA	Pharmaceuticals and Medical Devices Agency
PMMSY	Pradhan Mantri Matsya Sampada Yojana
PPP	Public–Private Partnership
QSP	Quantitative Systems Pharmacology
RCGM	Review Committee on Genetic Manipulation
RDI	Research, Development & Innovation Scheme
SPF	Specific-Pathogen-Free
SWOT	Strengths and Weaknesses, alongside external Opportunities and Threats
UMMID	Unique Methods of Management and treatment of Inherited Disorders
VC	Venture Capital

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सत्यमेव जयते

NITI Aayog