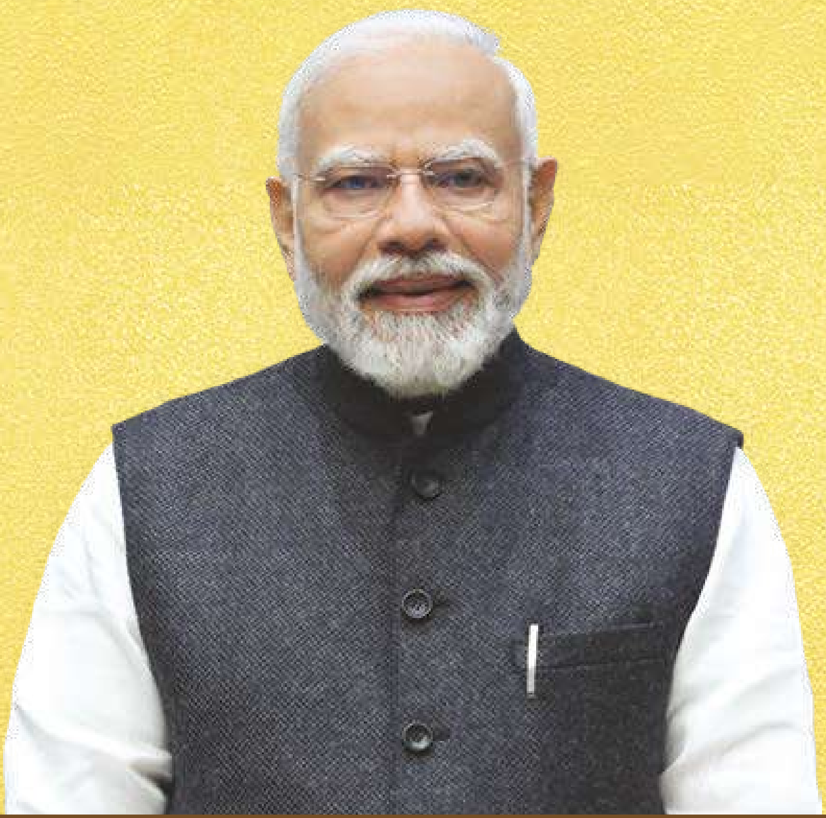
Vision Document

Emerging Science, Technology, and Innovation Conclave
ESTIC 2025

Imagine. Innovate. Inspire.
for
Viksit Bharat 2047



"Our Government is continuously working to encourage research and innovation among the youth. This is important to realise our dream of a Viksit Bharat"

Shri Narendra Modi

Hon'ble Prime Minister

डॉ. जितेन्द्र सिंह
राज्य मंत्री (स्वतंत्र प्रभार),
विज्ञान और प्रौद्योगिकी मंत्रालय,
पृथ्वी विज्ञान मंत्रालय,
राज्य मंत्री प्रधान मंत्री कार्यालय,
कार्मिक, लोक शिकायत तथा पेंशन मंत्रालय,
परमाणु उर्जा विभाग तथा अंतरिक्ष विभाग,
भारत सरकार

सत्यमेव जयते

DR. JITENDRA SINGH
Minister of State (Independent Charge),
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Ministry of Personnel, Public Grievances and Pensions,
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Government of India

Message

India today stands at a defining moment in its scientific journey.

Over the past eleven years, the nation has witnessed an extraordinary transformation across the spectrum of science, technology, and innovation. From pioneering advances in space and nuclear technologies to global leadership in digital public infrastructure, renewable energy, deep-tech startups, and biotechnology, India's S&T ecosystem has emerged as a key pillar of national progress and global collaboration.

The vision of Viksit Bharat@2047 a developed, self-reliant, and technology-driven India is deeply rooted in scientific excellence, innovation, and entrepreneurship.

The last decade has shown how science can drive socio-economic change, empower citizens, and create sustainable livelihoods. Whether through affordable healthcare innovations, precision agriculture, clean energy transitions, or advances in frontier areas such as quantum technologies, artificial intelligence, and materials science, India's scientific community continues to shape a resilient and inclusive future.

As we look ahead, initiatives such as the Emerging Science, Technology and Innovation Conclave (ESTIC) 2025 reflect India's national aspiration to accelerate discovery, innovation, and collaboration across the scientific spectrum, nurture collaboration among researchers, industries, StartUps and policymakers. Bringing together researchers, industries, startups, and policymakers, ESTIC 2025 will serve as a catalyst for breakthrough ideas, global partnerships, and next-generation technologies. It will chart the innovation pathways that will power India's progress toward Viksit Bharat and strengthen our leadership in the global S&T ecosystem.

India's journey in science and technology is not merely a record of achievements, it is a reflection of our collective vision, resilience, and determination to shape a better future. The years ahead will be pivotal in transforming this momentum into path-breaking innovations that address the world's pressing challenges from climate change and energy security to sustainable food systems and equitable access to technology.

The strides of the past eleven years strengthen our confidence for the future. Indian science will continue to guide our journey toward Viksit Bharat@2047, inspiring every generation to dream, innovate, and transform the nation

(Dr. Jitendra Singh)
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अजय के. सूद
भारत सरकार के प्रमुख वैज्ञानिक सलाहकार
Ajay K. Sood
Principal Scientific Adviser to the Govt. of India

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Foreword

India's scientific and technological landscape is entering a defining era—one that demands not only breakthrough innovations but also systemic integration, anticipatory governance, and a shared sense of national purpose.

The Emerging Science, Technology and Innovation Conclave (ESTIC) is a pioneering initiative designed to meet the demands of this critical juncture. It provides a unified, forward-looking platform to steer India's science and technology landscape over the next two decades, in alignment with the transformative goals of *Viksit Bharat@2047*.

This Vision Document is the outcome of a collaborative effort involving 13 ministries and departments, each bringing its domain expertise and strategic mandate to the table. It reflects a collective commitment to harness science and technology as instruments of inclusive development, global competitiveness, and societal resilience. It is not a static plan but a dynamic instrument—designed to evolve with emerging challenges, opportunities, disruptive technologies, and shifting geopolitical realities.

At its core are eleven frontier themes: Advanced Materials & Manufacturing, Quantum Science & Technology, Energy Environment & Climate, Artificial Intelligence, Electronics and Semiconductor Manufacturing, Bio-Manufacturing, Blue Economy, Space Technologies, Digital Communications, Emerging Agriculture Technologies, and Health and Medical Technologies. Each theme is explored through a multidimensional lens—examining global trends, India's current positioning, and the strategic imperatives required to lead in a rapidly evolving world.

The document places strong emphasis on strategic clarity as a foundational principle for long-term national planning. It articulates thematic missions, outlines India's global aspirations, and presents actionable roadmaps. At the same time, the document remains grounded in indigenous strengths: our rich scientific heritage, institutional depth, demographic dividend, and growing innovation capacity. This dual lens—global relevance and local resilience—ensures that India's S&T roadmap is not only visionary but also implementable.

By embedding clarity of purpose into each thematic area, the Vision Document empowers ministries, institutions, and innovators to align their efforts, measure progress, and adapt dynamically—ensuring that India's scientific advancement is not only accelerated, but also deeply anchored in national interest.

Above all, this Vision Document is a call to a collective leadership. As India charts its course toward *Viksit Bharat@2047*, it serves as both a compass and a catalyst, providing direction and momentum to galvanize a whole-of-government and whole-of-society approach to science and technology.

The path ahead will require agility in decision-making, deep collaboration across sectors, and sustained investment in knowledge, talent, and infrastructure.

This document invites scientists, policymakers, industry leaders, academic institutions, and young innovators to co-create a future where technology is not only a driver of economic growth, but a force for equity, sustainability, and national pride.

(Ajay K Sood)

Date: 31st October 2025

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Vision Summary

The Emerging Science, Technology & Innovation Conclave (ESTIC), organised by the Department of Science and Technology in association with 12 other Ministries and Departments, under the guidance of the Office of Principal Scientific Adviser to the Government of India, is a pioneering national initiative designed to provide a single unique global platform to meet the national-international visionaries, policy makers, S&T leaders, think tanks, pioneer researchers, academicians, industrialists, young scientists to discuss S&T directions, futuristic and emerging technologies, and technology-driven solutions for addressing global and societal challenges.

ESTIC 2025 focuses on advancing Emerging Science & Technology (S&T); engaging future Science & Technology Leaders; fostering Collaborations; and celebrating Stakeholder Contributions. Together, these objectives underscore a collective vision for accelerating discovery, enabling innovation-led growth, and fostering convergence among government, industry, academia, and start-ups.

The ESTIC framework is anchored in eleven thematic areas that represent the pillars of India's future-ready S&T ecosystem: Advanced Materials and Manufacturing, Artificial Intelligence, Bio-Manufacturing, Blue Economy, Digital Communications, Electronics and Semiconductor Manufacturing, Emerging Agricultural Technologies, Energy, Environment and Climate, Health and Medical Technologies, Quantum Science and Technology, and Space Technologies. Each of these areas embodies the intersection of science, innovation, and national development, driving India's transformation into a global technology leader.

The Vision Document

The Vision Document, developed under ESTIC, serves as a strategic blueprint to guide the nation's science and technology agenda.

It lays out our priorities that are well defined and people-centric across the thematic areas. In semiconductors and electronics, the emphasis is on trusted value chains, from design to packaging, supported by a skilled talent pipeline. Artificial intelligence must be safe, ethical and useful, with measurable applications in agriculture, healthcare, mobility and governance. Quantum technologies require strengthening communications, sensing computation and materials through a network of hubs that connects institutions and researchers across the country. Indigenous applications will be developed through Indian startups.

In biotechnology and health, we will scale bio-manufacturing, diagnostics and med-tech with procurement-friendly pathways so that innovation reaches district facilities and tertiary hospitals. Action towards climate change and clean energy goals will be target oriented towards solar, green hydrogen, CCUS and resilience plans that states and cities can execute. Digital communications must remain secure and interoperable so that access reaches the last mile. Space applications will keep enabling agriculture, disaster risk reduction, navigation and logistics, while opening doors for new enterprises.

The document lays out a cohesive and forward-looking framework for strengthening institutional linkages, and fostering coordinated action across ministries and sectors. The document is oriented so that India's scientific advancement is both mission-driven and inclusive, aligning technological progress with national goals such as sustainability, resilience, and societal well-being. With clarity and direction for the government and all stakeholders, it can help reduce fragmentation and promote synergy across the national science, technology, and innovation ecosystem.

Relevance of the Vision Document & way forward

The Vision Document acts as a strategic compass, guiding policymakers, ministries, and stakeholders in making evidence-based decisions for investment, innovation, and policy formulation focused on the 11 thematic areas shaping the nation's STI ecosystem. By connecting emerging technologies to developmental goals, it promotes inter-ministerial coordination, resource optimization, and a unified national approach. Its relevance lies in transforming India's vast scientific potential into tangible outcomes that enhance national competitiveness and contribute meaningfully to a self-reliant Viksit Bharat 2047.

To realize this vision, research institutions, industry, and start-ups must align their roadmaps with the identified priorities, building strong partnerships through knowledge, expertise and infrastructure sharing and work towards translating scientific progress into cutting-edge innovations and frontline technologies useful for the industry and for society.

The Vision Document calls for continued collaboration among ministries, research institutions, industry, academia, and start-ups to translate scientific ideas into real-world applications, specifically in emerging areas of National Priority. Moving forward, timely reviews and sustained policy alignment will ensure that India's science and technology landscape remains dynamic, globally competitive, and responsive to the needs of both industry and society.

A sustained focus on translating science, technology, and innovation into tangible societal benefits, by focusing on the thematic areas that have been identified as priorities for the Nation, will ensure that innovation drives inclusive and sustainable growth. In essence, this Vision Document is not merely a roadmap but a collective commitment to harness the power of science, technology, and innovation for building a developed, resilient, self-reliant India that is a global leader in S&T.

Advanced Materials & Manufacturing

Council of Scientific & Industrial Research (CSIR)

Executive Summary

Advanced Materials and Manufacturing are cornerstones of next-generation technologies with wide-ranging applications in aerospace, defence, energy, healthcare, agriculture, electronics, and mobility. They enable breakthroughs in composites, ceramics, polymers, and metallic alloys, supporting precision engineering, high-performance systems, and sustainable production. Globally, Advanced Materials and Manufacturing are expected to generate $2–3 trillion in economic value by 2040, making leadership in this domain vital for competitiveness and security. India, with its strong academic foundation, vibrant start-up ecosystem, and expanding industrial base, is well placed to seize this opportunity. A coordinated national vision can accelerate technology translation, build sovereign capability, and align innovations with national missions, positioning India as a global leader in Advanced Materials and Manufacturing.

Introduction

India stands at a pivotal moment where self-reliance, technology leadership, and sustainable development are national priorities, and the timing is ideal for a vision document on Advanced Materials and Manufacturing. As global competition intensifies and materials science advances at an unprecedented pace, there is an urgent need for clean, efficient, and sustainable technologies based on advanced materials that are central to innovations across sectors such as defence, energy, healthcare, agriculture, electronics, and manufacturing.

India is also entering a transformative era in manufacturing, propelled by the growing demand for advanced materials and precision engineering in strategic sectors such as aerospace, automotive, biomedical, defence, and energy. The fabrication of complex, multi-functional components using composites, ceramics, polymers, and metallic alloys requires micro- and nano-level precision, adaptability, and cost efficiency. While some of these technologies are already mature, many remain in developmental stages and require effective translation mechanisms to move from laboratory-scale research to industrial-scale implementation.

At the same time, India's robust academic foundation, emerging start-up ecosystem, and growing industrial demand create a ripe environment for translating research into scalable solutions. Updating this vision will enable the country to consolidate fragmented efforts, address critical infrastructure gaps, and align material innovations with our national goals—Viksit Bharat@2047 and Net Zero 2070 making it a timely and strategic national imperative.

Global Scenario

Globally, research and development in advanced materials and manufacturing is progressing at a rapid pace, with countries such as the United States, China, Japan, South Korea, and the UK making significant advances in areas including high-entropy alloys, critical minerals, additive manufacturing, biomaterials, advanced polymers, carbon nanomaterials, metamaterials, quantum materials, energy materials, and low-dimensional materials. These advancements are being accelerated through strong institutional frameworks, dedicated national initiatives, and active academia- industry collaborations. Such coordinated efforts are enabling global leaders to move swiftly from research breakthroughs to large-scale industrial applications.

India's Global Positioning in Advanced Materials & Manufacturing

India possesses a robust academic and research base in advanced materials, supported by national missions such as the Nano Mission, National Green Hydrogen Mission, National Critical Mineral Mission, National Quantum Mission, India Semiconductor Mission, and the National Strategy for Additive Manufacturing. These initiatives provide a foundation for targeted R&D, infrastructure creation, and industry engagement. Notable strengths include thermoelectric and triboelectric materials, battery materials, advanced ceramics, aerospace and defence alloys, hydrogen production and storage materials, and porous materials. Figure 1 illustrates the number of research groups engaged in materials research under various themes or categories.

In advanced manufacturing, India has made strides in additive manufacturing, AI-driven manufacturing, robotics and automation, smart materials, and nano-manufacturing, with several technologies under active development in leading institutions (Figure 1). However, challenges remain, including limited large-scale deployment, infrastructure gaps, shortage of skilled manpower, weak indigenous tool development, and insufficient integration with the Industry 4.0 ecosystem. Unlike global leaders who are transitioning to industrial-scale deployment, India largely remains in the exploratory and prototyping stage for many material classes. Strengthening AI/ML-driven material discovery, scalable manufacturing infrastructure, and academia–industry partnerships will be critical.

Despite these gaps, India has made progress in sustainable materials and indigenous technologies aligned with national priorities. Unique advanced processing facilities such as Electron Beam Melting Additive Manufacturing, a Pilot Plant for Rare Earth Magnet manufacturing, Laser-assisted Machining, and an Optoelectronic setup have been established across various academic and R&D institutions in India. Using these facilities, several components and prototypes have been developed for diverse applications, including Li-ion batteries, magnets, fuel cells, biomedical devices, aerospace, and communication technologies (Figure 2). To elevate its global standing, a coordinated national push is essential, focusing on infrastructure investment, cross-sectoral collaboration, and strategic development across domains such as advanced alloys, energy materials, critical minerals, biopolymers, biomaterials, carbon nanomaterials, and low-dimensional materials.

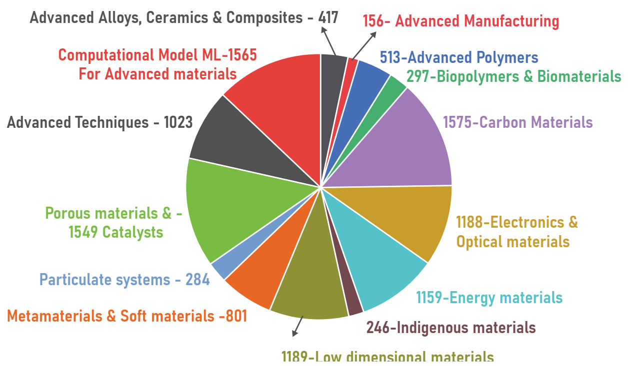


Figure 1(left) depicting the number of research groups working on different themes/areas under Advanced Materials in India. While the total number of such research groups in the country is approximately 5200, many practice in multiple areas. The data is sourced from citation-based evaluation tools InCites and Web of Science, both from Clarivate. Note: The term, Indigenous Materials, refers to naturally occurring, locally sourced materials. Quantum materials are part of low dimensional/ electronic & optical materials and therefore, not shown explicitly.

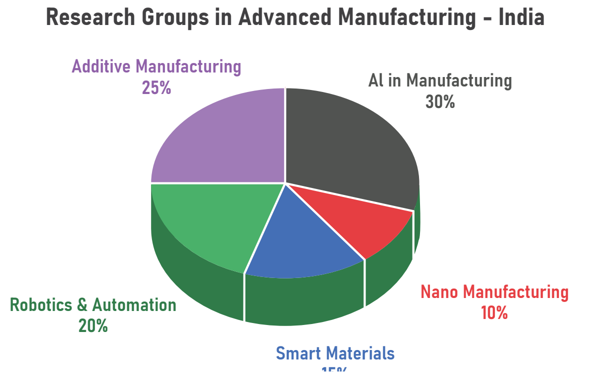


Figure 1 (right) shows the details of research groups working across various verticals under Advanced Manufacturing in India. The data is sourced from Web of Science (Clarivate).

Figure 2 shows the details of research groups working across various verticals under Advanced Manufacturing in India. The data is sourced from Web of Science (Clarivate)

Vision Statement

To design, develop, and produce advanced materials, manufacturing technologies, devices, and processes that convert sustainable scientific inventions into market-ready solutions through strong academia-industry collaboration, advancing self-reliance, global competitiveness, and a highly skilled national talent pool in AM&M.

In advanced materials, build a discovery-to-deployment pipeline across composites, ceramics, polymers, metallic/alloy systems, energy and critical-mineral materials, and carbon nano/low-dimensional classes. Couple AI/ML-guided design with scalable synthesis and rigorous characterization to deliver materials that are high-performance, reliable, sustainable, and ready for manufacturing and certification at industrial scale in energy, healthcare, agriculture, defence, space, electronics, mobility, and aerospace. Prioritize indigenous capability and sovereign IP.

In manufacturing technologies; create an agile, technology-driven, globally competitive ecosystem that harnesses digitalization, automation, and next-generation fabrication—additive manufacturing, micro/nano-fabrication, AI/ML-integrated design and process control, smart factories, robotics, precision metrology, and surface engineering—with seamless Industry 4.0 (and beyond) integration, strong domestic machine/tool development, and accelerated commercialization of scalable, high-performance solutions.

In devices; enable design, prototyping, validation, and standards-compliant scaling of medical and assistive devices, sensors, power and communication modules, aerospace/defence subsystems, and other high-value products by integrating materials selection with manufacturing-ready architectures, reliability engineering, and clear certification pathways—so innovations move rapidly from labs to production and deployment.

In processes; institutionalize green, precise, and data-rich methods—ranging from additive and micro/nano-machining to advanced surface engineering and in-line metrology—anchored in digital twins, real-time analytics, and secure cyber-physical systems to ensure repeatability, traceability, quality, and cost efficiency at industrial scale.

To enable all of the above, provide robust infrastructure, 24/7 shared facilities, targeted skill development, and translational platforms that accelerate the shift from laboratory to production while tightly connecting universities, R&D centres, start-ups, and industry—delivering a self-reliant, sustainable, export-competitive AM&M ecosystem aligned with national missions, including Viksit Bharat 2047 and Net Zero 2070.

Mission Statement

- Design, validate, and scale advanced materials, manufacturing technologies, devices, and processes etc.
- Establish regional Centres of Excellence and 24/7 shared hubs for synthesis, characterization, fabrication, and computational modelling.
- Fund high-quality basic and translational R&D with clear TRL→MRL pathways.
- Build an Industry-4.0-ready skilled human resource through hands-on training, digital/AI platforms, and structured skilling pipelines.
- Catalyse academia–industry–startup consortia to convert prototypes into production and commercialize at scale.
- Strengthening indigenous machines, tooling, and process-control software to reduce import dependence.
- Secure sovereign IP and resilient supply chains in strategic materials and processes.
- Embed cyber-physical security standards across critical manufacturing lines.
- Prioritize strategic sectors such as energy, automotive, healthcare, agriculture, defence, space, and electronics etc.
- Deliver self-reliance, global competitiveness, and sustainable growth aligned with Viksit Bharat 2047 and Net Zero 2070.

Discussion

The vision and mission statements of this initiative are rooted in foundational principles that reflect India's aspirations for scientific leadership and technological sovereignty, directed towards developing indigenous capabilities in critical sectors such as energy, healthcare, agriculture, defence, and electronics, thereby reducing dependency on external sources. The vision also emphasizes collaborative partnerships between academia and industry, both within India and internationally. A strong focus on nurturing high-quality basic research to open new frontiers in advanced materials and manufacturing is built into the statements. Human resource development, with particular emphasis on creating a skilled and motivated scientific workforce through hands-on training, is another key element of the vision and mission.

In this context, advanced manufacturing becomes a vital factor in shaping the technological future of the nation. Investment in indigenous additive manufacturing technologies with large-scale production capability is essential, as rapid prototyping with complex geometries especially using customized materials holds immense potential in critical sectors such as healthcare and electronics. Smart manufacturing, driven by digital integration through real-time analytics, IoT, and AI-enhanced systems, is central to modernizing legacy factories, minimizing waste, and maximizing productivity. Precision and micro-/nano-manufacturing technologies, such as ultra-fine machining, laser- and beam-based processing, and advanced polishing, are crucial for next-generation aerospace, optical, and biomedical components. Human-centric automation, including robotics and collaborative robots (cobots), must be designed to complement India's labour-intensive industries while enhancing throughput, quality, and worker safety.

The development of specialty materials and products such as composites, biomedical devices, and assistive technologies will play a vital role in addressing national needs in healthcare, mobility, and defence. This effort should be reinforced by innovative collaboration models such as e-Gurukul platforms, adjunct faculty appointments, and partnerships with non-resident Indian (NRI) experts to enable long-term knowledge exchange and co-development between Indian institutions and global leaders.

Together, these principles and priorities underscore a bold and actionable roadmap for transforming India into a global leader in advanced materials and manufacturing, fully aligned with national missions.

Strategic Goals and Road Map

An inclusive national thrust is the need of the hour to fast-track R&D in advanced materials and manufacturing in India. This effort can be structured around four core components.

(i) Translational Research

The first component focuses on translational research, supporting projects that involve academia, start-ups, and industry. The aim is to translate lab-level research innovations into commercial ventures.

(ii) Human Resource Development and Outreach

The second component emphasizes human resource development and outreach, aimed at cultivating a skilled, innovative workforce through research methodology labs, training programs on prototyping, and knowledge-sharing workshops involving national and international experts. Outreach activities will help spread scientific awareness and entrepreneurial culture among students, educators, and the public. A core strategic goal is to empower the workforce through digital platforms and simulation-based tools, making them agile and future-ready for next-generation manufacturing environments.

(iii) Shared Facilities for Materials Research

The third component involves establishing state-of-the-art shared research hubs equipped with advanced tools for material synthesis, characterization, fabrication, and computational modelling. These centralized facilities should operate under a vendor–partner model to ensure sustainability, while remaining accessible to academia, start-ups, and industry on a 24/7 basis. To complement this, a national push to scale up precision manufacturing through investments in micro-/nano-machines, surface engineering technologies, and functional coatings will enable the societal deployment of high-performance products in electronics, optics, aerospace, and biomedicine.

(iv) Basic Research and International Access

The fourth component supports cutting-edge, discovery-driven basic research and improved access to international research facilities. This includes promoting AI/ML integration in materials science, enabling access to global infrastructure, and strengthening national research capabilities. Strategic goals here include developing cyber-physical security infrastructure through joint industry–academia labs to protect manufacturing networks, and accelerating biomedical and composite manufacturing hubs to meet growing demand for high-quality solutions in healthcare, mobility, and strategic sectors.

Together, these four components and their aligned goals provide a robust and scalable framework for building India's leadership in advanced materials and manufacturing.

Conclusion

This vision document outlines a futuristic and tactical approach to empower India in advanced materials and manufacturing, enabling the nation to achieve global standards and move beyond them. In addition to clearly articulating the vision and mission, the document suggests several pathways, including technology-oriented projects, technical and research skill development, establishment of state-of-the-art shared research facilities, improved access to international experimental and computational facilities, and basic research oriented projects as the way forward to enhance R&D in advanced materials and manufacturing. Building sovereign capability in critical materials, fostering indigenous tooling and manufacturing, and securing resilient supply chains will not only reduce external dependence but also create new avenues for global leadership.

Nurturing existing research expertise to its full potential, expanding R&D into translational activities, and upskilling the scientific and technical community are definitive steps toward establishing high standards in large-scale manufacturing of innovative material products. Transforming the current R&D ecosystem into a fully innovation-driven one will also require strong academia–industry collaborations, new strategies, and supportive policies.

Together, these efforts will enable India to move decisively from being a participant in the global advanced materials and manufacturing landscape to becoming a leader, fully aligned with the national priorities of Viksit Bharat @ 2047 and Net Zero 2070. This is not only a technological imperative but also a strategic necessity for India's economic growth, national security, and sustainable development.

Artificial Intelligence

Ministry of Electronics and Information Technology (MeitY)

Executive Summary

Artificial Intelligence (AI) stands as a transformative force with the potential to address critical societal challenges, particularly in healthcare, defence, governance, agriculture, education, environmental sustainability, and social inclusion. India, with its scale, diversity, and digital backbone, is uniquely positioned to harness AI for inclusive growth across population. The thematic focus on **"AI for Social Impact"** seeks to explore, enable, and accelerate the positive influence of AI on communities. This vision comes to life through the IndiaAI Mission, which brings together efforts to push AI innovation forward, create inclusive and representative datasets (through AIkosh), strengthen research and development through startups, and make sure AI benefits reach every citizen. This document articulates India's strategic approach to leveraging AI for social impact, emphasizing responsible innovation, ethical deployment, and community-oriented development. The roadmap underlines India's global leadership ambitions and a commitment to inclusive, context-aware, and sustainable AI advancements.

Introduction

Artificial Intelligence (AI) stands at the forefront of technological innovation, offering transformative potential across sectors. The intersection of demographic scale and socio-linguistic diversity makes India uniquely poised to harness the transformative potential of responsible AI, provided its implementation reflects the lived realities of access, equity, and localized deployment across India's diverse regions. India, with its talented and growing workforce, is well placed to not only improve outcomes across multiple sectors including the public services through digital governance but also set an example globally in how AI can be used ethically and for real impact.

India's AI mission's key components are operationalized through consortium lead initiatives such as **Bhashini** for Indian language tools and BharatGen for sovereign foundational model development. They are helping build AI that speaks many Indian languages, understands its cultural diversity, and works in ways that truly fit local needs. Together, these efforts reflect India's drive for technological self-reliance, responsible AI, and solutions that mirror the richness and aspirations of its people.

Global Scenario

Artificial Intelligence has rapidly transitioned from a niche research field to a transformative force across the globe. As of 2025, the global AI market is valued at $391 billion and is projected to reach $1.81 trillion by 2030, reflecting a compound annual growth rate (CAGR) of 35.9% . This surge is driven by widespread enterprise adoption, increased consumer interaction with AI, and integration in public sector operations. AI is now being applied to advance all 17 United Nations Sustainable Development Goals (SDGs), with particularly high impact in healthcare, education, climate action, clean energy, and sustainable cities—areas that account for 60% of not-for-profit AI deployments.

While Artificial Intelligence has rapidly evolved into a transformative force globally, the stakes are uniquely high for India. With over a billion people, linguistic diversity, and persistent socioeconomic disparities, India arguably needs AI more urgently than any other nation. From scaling healthcare access in remote regions to transforming educational delivery in under-resourced schools, AI offers not just an opportunity but an imperative. However, the road to achieving social-scale AI is far from trivial. The cost of deploying advanced AI systems has dropped dramatically, by over 280-fold between November 2022 and October 2024, making AI more accessible and affordable worldwide, yet affordability alone does not guarantee equitable adoption. Challenges remain in building the last mile infrastructure, ensuring availability of quality local language data, fostering trust through transparency and developing context aware solutions that work across India's diverse population. Addressing these gaps will be key in unlocking AI's full potential for social impact.

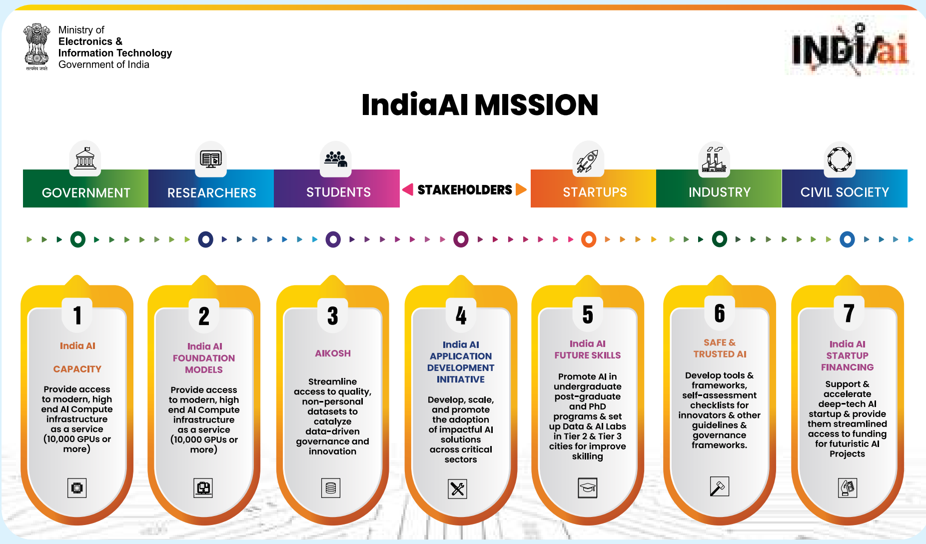
India's Global Positioning

In India, the momentum is even more pronounced, India leads globally in AI adoption, with a 30% adoption rate compared to the global average of 26%. Despite such adoption in urban and enterprise contexts, vast sections of India's population, especially in rural, tribal, and vernacular communities remain untouched by AI-driven interventions. While there is enthusiasm for AI among Indian users, the gap between consumer awareness and enterprise-level adoption remains stark. Regulatory ambiguity, data localization mandates, and sector-specific guidelines have further slowed responsible deployment, especially in finance, healthcare, and governance. The country's AI industry is supported by robust government initiatives such as the National AI Strategy and the IndiaAI Mission, which focus on public good and national development. AI is being actively integrated into governance, healthcare, education, and agriculture. For example, AI-driven platforms are making quality education accessible to remote communities, while precision agriculture solutions are helping farmers optimize yields and manage resources more efficiently. India's Digital Public Infrastructure (DPI), including Aadhaar and UPI, is now being enhanced with AI to improve service delivery and efficiency, as seen in large-scale events like Mahakumbh 2025. While India's DPI provides a robust backbone, learnings from these efforts underscore the need for deeper participatory design, explainability, and bottom-up inclusivity when layering AI onto public infrastructure. Without these, AI may amplify biases or deepen the digital divide.

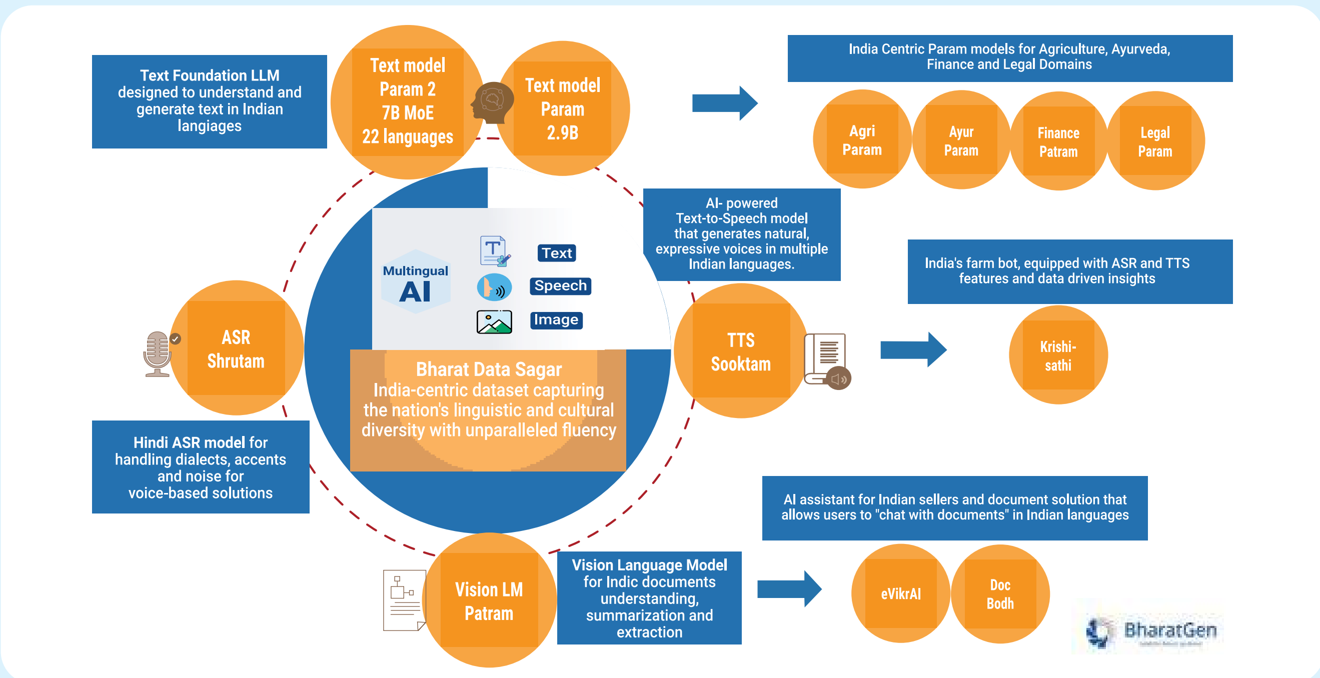
Globally, AI adoption is accelerating, with notable advancements in medicine, agriculture, disaster response, and public services. However, the deployment of AI for social good remains uneven. Barriers such as limited access to data, lack of contextualized solutions, ethical concerns, and resource constraints persist, especially in low-resource settings. Despite these challenges, successful pilots and projects demonstrate AI's potential to amplify social impact, improving lives, empowering communities, and supporting sustainable development goals (SDGs).

In the cabinet approved IndiaAI Mission 2024, the government allocated ₹10,372 crore over five years to strengthen AI capabilities. A key focus of this mission is the development of a high-end common computing facility. IndiaAI surpassed its initial GPU procurement target of 10,000 units long ago. Existing compute capacity exceeds 38,000+ Graphics Processing Units (GPUs) making it one of the most extensive AI compute infrastructures globally.

The approved IndiaAI Mission will propel innovation and build domestic capacities to ensure the tech sovereignty of India. It will also create highly skilled employment opportunities to harness the demographic dividend of the country. IndiaAI Mission will help India demonstrate to the world how this transformative technology can be used for social good and enhance its global competitiveness. **Overall, India has the potential to add US$359 billion to US$438 billion to its GDP on account of Gen AI adoption in 2029-30** over and above its baseline estimates which would represent an **additional 5.9% to 7.2% of GDP in 2029-30.**



BharatGen, a pioneering National Sovereign foundational LLM initiative in generative AI designed to revolutionize public service delivery and boost citizen engagement through developing a suite of foundational models in language, speech, and computer vision. The four key distinguishing features of BharatGen are the multilingual and multimodal nature of the sovereign foundation models; Bhartiya data set based building, and training; open-source platform and development of an ecosystem of generative AI research in the country. BharatGen includes a consortium of top AI researchers across premier academic institutions in India that include IIT Bombay, IIIT Hyderabad, IIT Mandi, IIT Kanpur, IIT Hyderabad, IIM Indore, and IIT Madras. These research groups are partnering with the government, industry, and startups to develop models, keeping in mind the linguistic and cultural diversity of India and inclusivity for citizens and to ensure equitable technological access across different socio-economic groups in the country.



Mission Statement

The strategic goal for India would be weaving AI into the very fabric of society not as a separate layer, but as something that naturally integrates with how systems function, how services are delivered, and how it facilitates ease of living for the population at large. This calls for AI that strengthens and complements existing structures, while making them more inclusive, responsive, and human-centered. This involves creating inclusive, scalable, and context-aware AI models, fostering participatory collaboration, empowering communities through capacity building, and ensuring ethical and accountable AI adoption.

Vision Statement

The objective is to catalyze the responsible and inclusive adoption of AI in a manner that directly addresses India's unique challenges and leverages its opportunities. This approach is grounded in indigenous contexts and tailored to Indian realities, drawing strength from the country's rich diversity of cultures, languages, traditions. By recognizing and respecting this pluralism, the aim is to design AI solutions that are not only technologically advanced but also socially and culturally relevant that capture the diverse ways of life across India and remain rooted in local contexts. The focus is on driving measurable social impact enhancing access, efficiency and equity, while fostering sustainable and inclusive development that benefits all sections of society. By aligning innovation with responsibility, the aim is to create an AI ecosystem that empowers communities, supports economic growth and upholds ethical standards.

Strategic Goal and Roadmap

i. **Leapfrogging using Inclusive AI Foundational Research:** Focus on marginalized and vulnerable groups by developing AI that respects linguistic and cultural diversity. Prioritize low-resource languages and implement symbolic, provenance-aware, and data-efficient AI models tailored for Indian contexts. Co-create solutions with end-users and communities to improve relevance and impact.

ii. **Ensure Ethical and Responsible AI:** Establish frameworks emphasizing transparency, fairness, privacy, and accountability. Address biases in AI models, implement responsible data practices, conduct impact assessments, and provide grievance redressal systems particularly for high-stakes areas such as healthcare and welfare.

iii. **Build in Measurement and Scale of Impact:** Develop robust frameworks to evaluate and document AI-driven social initiatives, ensuring reach and efficacy in underrepresented demographics. Scale successful pilots through partnerships, open-source models, and continuous beneficiary feedback.

iv. **Foster Multi-Stakeholder Collaboration:** Promote partnerships between government, academia, industry, and civil society. Encourage interdisciplinary collaboration and the use of open platforms and data-sharing frameworks for AI innovation, with decentralized approaches tailored to India's diversity.

v. **Build Capacity and Awareness:** Enhance understanding of AI's potential and risks via accessible education, training, and awareness campaigns for policymakers, practitioners, students, and communities. Employ multilingual resources and leverage mentorship networks and incubators for grassroots innovation.

Conclusion

AI offers unprecedented opportunities to address complex social challenges. By aligning innovation with ethical principles and inclusivity, we can unlock AI's full potential for social good. This vision calls for collective action to ensure that AI serves humanity, uplifts the underserved, and contributes to a fairer, more sustainable world. As India aspires to lead globally in responsible and inclusive AI, it must invest in foundational R&D that reflects its own values: context-awareness, symbolic interpretability, data efficiency, and provenance-traceable pipelines. With the right strategic focus, India can not only benefit from global AI advances but also contribute new paradigms to the world.

Bio-manufacturing

Department of Biotechnology

Executive Summary

Biomanufacturing has emerged as an indispensable alternative to typical chemical factory manufacturing. Biomanufacturing is a method of producing commercially viable biomolecules via utilisation of a biological platform, including those based on microbial, animal and plant cells. A range of products can be potentially produced with these platforms, such as therapeutics, drugs and nutraceuticals, environmentally friendly bioplastics, smart proteins, and biofuels. Biomanufacturing can revolutionise industries via renewable, sustainable and scalable biological production systems. The rapid growth in advanced fermentation technologies, synthetic biology, and bio-based materials, with heavy economic investment globally, can be realised to secure the leadership in biomanufacturing. In line with this, India has already been recognised as the "pharmacy of the world" and is poised to become a global hub of biomanufacturing, aiming to achieve a $300 billion bioeconomy by 2030. To accelerate sustainable high-performance biomanufacturing to ensure economic, environmental, and employment benefits through biotechnology, India has recently introduced the BioE3 policy. This is also in alignment with the "Net-Zero" carbon economy and the "Lifestyle for Environment (LiFE)" nationally important initiatives. In a nutshell, India is quickly positioning itself as a global biomanufacturing hub through innovation and collaboration with academia, industries, business, and philanthropic stakeholders.

Introduction

Biomanufacturing is a method of producing commercially important biomolecules by utilising biological systems, including microbial, animal, and plant cells. Advancements in biomanufacturing are now leading to the development of completely novel products with lower costs and minimal impact on the environment. With significant developments in the areas of gene therapy, precision medicine, and drug discovery, biomanufacturing has now become the central pillar of the global economy and security. By connecting scientists with industry and the market, biomanufacturing aims to scale up innovative products developed in the lab to strengthen national security and foster sustainable economic growth. It has applications across the agricultural, pharmaceutical, diagnostics, food, and several other industrial processes.

Global Scenario

With increasing demand and the need to focus on sustainable alternatives, biomanufacturing is undergoing significant growth and transformation (Figure 1). Advances in artificial intelligence and machine learning are further speeding up product development by simulating experiments and predicting molecular behaviour. New biotech startups are reshaping the industry by integrating disruptive technologies with innovative business models.

Currently, North America, particularly the United States, dominates the global biomanufacturing landscape due to early adoption of bioprocess technologies and robust venture capital ecosystems. In contrast, the Asia-Pacific region is the fastest-growing in biomanufacturing, driven by strong government initiatives and a surge in biotech startups in countries such as China, India, South Korea, and Japan.

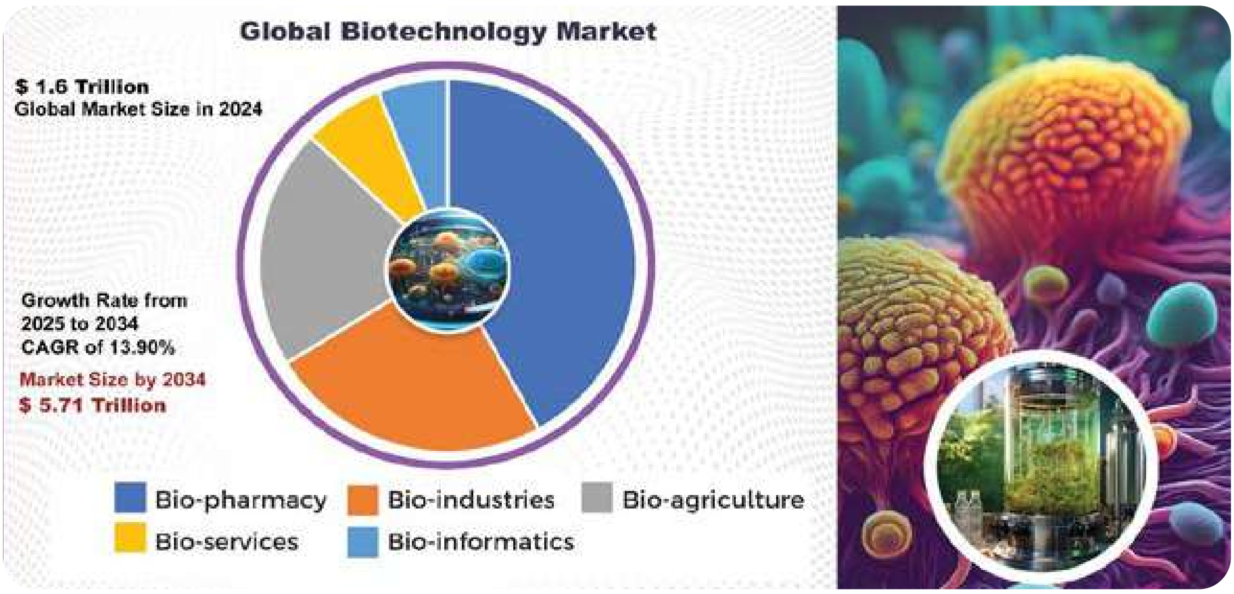


Figure 1: Market survey data for biomanufacturing (Courtesy: https://www.precedenceresearch.com/biotechnology-market)

India's Global Positioning

India is rapidly emerging as a biomanufacturing hub. The BioE3 policy of the Department of Biotechnology emphasises establishing Biomanufacturing and Bio-AI hubs and Biofoundaries across the nation to bridge the gap between lab-scale innovations and commercial production by targeting six strategic sectors for sustainable growth, including high-value bio-based chemicals, biopolymers, and enzymes; smart proteins and functional foods; precision biotherapeutics; climate resilient agriculture; carbon capture and utilisation; and marine and space research. Despite its progress, the field still faces significant challenges in scaling up production, maintaining consistent quality, and navigating complex regulations. Nevertheless, biomanufacturing stands at the forefront of innovation, poised to transform industries and improve lives in the years to come. The objective of this document is to establish a framework that positions India at the forefront of innovative research aimed at revolutionising biomanufacturing.

Vision Statement

India aims to build a sustainable, resilient, and health-centred future through the utilisation of biological sciences to develop life-saving medications, renewable materials, and nutritious food. This initiative aims to establish a world where biology supplants industries that are heavily polluting, improves global health outcomes, and facilitates equitable access to essential products for all individuals.

Mission Statement

In alignment with the national goal of Viksit Bharat@2047, biomanufacturing is guided by certain core principles and values that ensure responsible usage of technology for a sustainable future. One of the major goals is to reduce the impact of manufacturing processes on the environment by seeking greener alternatives using biological systems. The second important focus is affordability, where essential products such as food, medicines, and other necessities can become available to all sections of society. The field of biomanufacturing thrives on innovation with integrity, aiming to drive economic growth while upholding the highest standards of safety, ethics, and transparency. Collaboration and co-development are other key values, connecting scientists with industry, market, and government bodies to bridge the gap between discovery and commercialisation. Development of a skilled workforce capable of responding to health crises and climate-related challenges is also crucial for the long-term success of the field. While these principles form the foundation of the biomanufacturing revolution underway, India's mission to transition to a bio-based economy by advancing biomanufacturing technologies, scaling sustainable methods, and enabling global access to safe, affordable biologically-made products would have the following key actions:

- Develop functional foods and nutraceuticals for preventing chronic diseases and malnutrition.
- Develop resilient crops to mitigate the impact of climate change.
- Integrate synthetic biology and AI to produce novel compounds of high value.
- Develop a skilled workforce in the area of biotechnology and biomanufacturing.
- Establish state-of-the-art biomanufacturing facilities and pilot plants for large-scale production of commercially relevant products.
- Strengthen academic-industry collaborations to address real-world challenges.
- Boost bioeconomy through technology commercialisation and industry linkages.
- Promote eco-friendly and sustainable solutions while enhancing biomanufacturing capabilities.

Strategic Goals and Roadmap

With a special focus on biomanufacturing, India is enhancing its efforts in transitioning from energy-intensive chemical manufacturing to bio-based, renewable, and sustainable alternatives to alleviate its environmental footprint. The Ministry of New and Renewable Energy (MNRE) is investing heavily in improving the efficacy of producing renewable energies from various sources, including biogenic waste, which can be integrated with biomanufacturing to avoid coal-fired, fossil-based power, a step towards mitigating harmful environmental pollution. Today, artificial intelligence (AI) has penetrated every digital platform, leveraging its advantages, including, for example, integrating mechatronics with a biomanufacturing facility towards automation, improving bio-based products with precision, and minimising the bioproducts launch time. In accordance with that, the Biotechnology Research and Innovation Council – National Agri-Food and Biomanufacturing Institute (BRIC-NABI), a Department of Biotechnology organisation, acquired the high-performance computing facility "Param Smriti" (838 TeraFLOPs), which could help in leveraging its potential not only for instrument automation but also, essentially, for designing new biomolecules towards biomanufacturing (e.g., smart protein). Further, Indian institutes are not only partnering with other national institutes/industries but also international technology and innovation social enterprises, to take their R&D developments to the next level towards large-scale commercialisation, especially in agri-food biomanufacturing, and biotherapeutics. With the above-mentioned infrastructural facilities and collaboration with various stakeholders, including government and public funding, the way is paved towards reducing the cost of essential biomanufacturing products (e.g., biopharmaceuticals). This would help establish biomanufacturing facilities in remote areas, providing wider and easier accessibility to the underrepresented category. Furthermore, it has been realised that the skilled workforce needs to be augmented in the emerging biomanufacturing field and to counter that, the Department of Biotechnology is establishing biofoundries across the country, providing the platform and suitable ecosystems to eligible scholars to enhance their skills in biomanufacturing.

Furthermore, promisingly, the Department of Biotechnology introduced a major initiative on biomanufacturing, focusing on six major thematic sectors with concrete aims in line with the national development as follows: (i) Bio-Chemicals and Enzymes: Production of high-value bio-based chemicals, industrial enzymes, and biopolymers, (ii) Functional Foods and Smart Proteins: Meeting the increasing demand for food for the rapidly growing population in India and the globe through synthetic biology and metabolic engineering, (iii) Precision Biotherapeutics: Developing personalised medicine through cell and gene therapy, mRNA therapeutics, and monoclonal antibodies, (iv) Climate Resilient Agriculture: Achieving food security by promoting soil microbe-based R&D activities through innovative smart agriculture for the production of enhanced crop varieties, (v) Carbon Capture and Utilisation: Mitigating carbon emissions by 45% by 2030 by valorising CO_2 into high-value products and (vi) Futuristic Marine and Space Research: Unlocking new enzymes and bioactive compounds, opening a new avenue for the bioeconomy and to develop microbial biomanufacturing processes for space missions, and nutritious food for long-duration missions.

A typical biomanufacturing facility (for fermentative production of smart proteins and biomass conversion to low-calorie sugars) at BRIC-NABI, Mohali.

Conclusion

Biomanufacturing represents a transformative path toward a healthier, more sustainable, and resilient future. By scaling clean cell-based production methods, lowering the cost of life-saving medicines, building a skilled workforce, and accelerating innovation through technology and collaboration, the field is actively turning its vision into reality. Strategic goals, such as expanding infrastructure, improving access, and replacing petroleum-based materials, serve as practical and measurable steps that align with its core values: sustainability, equity, innovation, and resilience. Together, these efforts position biomanufacturing not just as a technology but as a long-term solution to some of the world's most pressing challenges in health, food, and the environment.

Blue Economy

Ministry of Earth Sciences

Executive Summary

India's 2047 Blue Economy vision aims to establish global leadership in sustainable ocean development by leveraging its vast coastline and Exclusive Economic Zone (EEZ). The strategy is driven by cutting-edge marine science and frontier technologies like AI, autonomous systems, and biotechnology to foster economic growth, environmental health, and social inclusion. Drawing on global best practices and building upon national initiatives like the Sagarmala Programme and Deep Ocean Mission, India is already advancing its fisheries, shipping, and renewable energy sectors.

The vision is supported by a clear roadmap with ambitious goals, including mapping 100% of the EEZ, achieving 50 GW of marine renewable energy, creating 10 million jobs, and transitioning all major ports to green, smart systems. The ultimate goal is to create a thriving, resilient, and inclusive Blue Economy aligned with India's long-term national aspirations.

Introduction

The Blue Economy is a multifaceted concept, subject to various interpretations across organizations, yet a consistent theme underscores its core definition "the sustainable use of ocean resources for economic growth, improved livelihoods, and job creation, while simultaneously preserving the health and integrity of ocean ecosystems". This encompasses a broad spectrum of activities, ranging from established sectors such as fisheries, coastal tourism, and maritime transport to burgeoning industries like offshore renewable energy, marine biotechnology, and deep-sea exploration and many others. A critical aspect of this definition is its emphasis on the three pillars of sustainability: environmental, economic, and social. This ensures that all initiatives are environmentally sound, socially inclusive, and climate resilient.

Sub-Sectors

Marine living resources	Maritime transport and shipping	Offshore renewable energy	Coastal tourism & heritage conservation	Marine biotechnology & blue innovation	Non-living resources	Disaster Resilience
Fisheries	Port infrastructure	Wind energy	Underwater & culture heritage	Bioprospecting & pharmaceuticals	Deep-sea mining	Ocean monitoring system
Aquaculture	Ship building & breaking	Tidal & wave energy	Cruise Tourism	Biofuels and bioplastics	Offshore oil and gas	Nature-based solutions
Seaweed	Maritime Logistics	OTEC & Hydrogen	Eco-tourism	Marine Start-ups	Gas hydrates exploration	Early warning

India's Blue Economy is rapidly emerging as a vital engine for national growth, strategically leveraging our extensive 11,098 km coastline and vast Economic Zone (EEZ). This maritime advantage offers long-term opportunities for economic development, environmental sustainability, and job creation across a wide range of ocean-based sectors.

The Blue Economy is evolving rapidly, powered by innovation and large-scale investments in advanced marine technologies. This global shift shows that sectors driven by science and technology can offer both economic and environmental benefits. With its extensive coastline, strategically important maritime location, and increasing investments in cutting-edge marine science and technology, India is exceptionally well-positioned to lead in this evolving global landscape.

To realize its Blue Economy vision, India will utilize key tools such as Ocean Observation Systems for real-time data and hazard warnings, ocean climate change projections for long term planning and evolving the policies, predictions of the state of the ocean for safety of people and installations at sea, Marine Spatial Planning (MSP) for efficient marine space allocation, and Ocean Accounting to integrate environmental health with economic performance. Complementing these are Integrated Coastal Zone Management (ICZM) for coordinated coastal development, and Marine Protected Areas (MPAs) for biodiversity conservation and ecosystem resilience. These tools, with the support of data driven methods, collectively drive integrated planning, safe installations and operations at sea and robust conservation for a sustainable Blue Economy.

This document lays out a clear vision for India's Blue Economy, with science, technology, ocean services and research & development (S&T&RD) as core drivers for its sustainable growth and national prosperity. It aims to provide a comprehensive framework that aligns sectoral development with broader national aspirations, particularly those outlined in the Vision Amrit Kaal.

Global Scenario

The ocean underpins the global economy, carrying over 80% of world trade by volume and supporting 350 million people in small-scale fisheries. More than 3.5 billion people rely on it for food security, while it also regulates the planet's health by producing half of the world's oxygen and absorbing a quarter of carbon dioxide emissions. The WWF values the ocean's asset base at USD 24 trillion, with annual economic activity of USD 2.5 trillion. Investment trends show growing momentum: marine technology attracted USD 2.4 billion in 2024, and funding for ocean-focused startups surged by 360% between 2023 and 2025.

Globally, several best practices offer lessons for India. Norway and Canada are advancing sustainable aquaculture through genetic tools, open-ocean cages, and IoT-based monitoring approaches that complement India's CMFRI and PMMSY initiatives. In shipping, Norway and Japan are leading in AI-driven port logistics and hydrogen-powered vessels, echoing India's Sagarmala and Green Hydrogen Mission. The UK and Australia are pioneering floating wind turbines and ocean thermal energy, aligning with India's offshore renewables research.

Tourism and heritage conservation also present opportunities: Australia uses smart sensors to certify clean beaches, while Canada applies digital tools for heritage preservation—efforts similar to India's coastal clean-up campaigns and the Lothal Maritime Museum. In biotechnology, the EU's microalgae-based antibiotics and Japan's seaweed-based materials mirror India's Seaweed Mission. For non-living resources, the US and Australia are advancing deep-sea mineral mapping and renewable-powered desalination, complementing India's Deep Ocean Mission and NIOT-led projects.

Benefits for India

Adopting these international best practices will significantly advance India's Blue Economy. Economically, Norway's and Canada's aquaculture technologies will boost seafood exports and offshore production, while Norway's and Japan's maritime innovations will enhance trade efficiency and shipbuilding. The UK's and Australia's renewable energy technologies will expand India's wind and OTEC markets, and Australia's and Canada's tourism technologies will drive revenue through sustainable practices. The EU's and Japan's biotechnology advancements will grow biotech exports and bio-material markets, and the USA's and Australia's resource extraction technologies will support petroleum and water security. Environmentally, these technologies reduce overfishing, emissions from shipping, pollution, coastal ecosystem stress, and energy-intensive extraction, aligning with India's net-zero 2070 goal. Socially, they create skilled jobs in aquaculture, shipping, fisheries, tourism, biotech, renewable energy, and resource sectors, empowering coastal communities. Innovation-wise, integrating IoT, AI, genetic tech, floating turbines, AR/V, bio-based solutions, AUVs, and sustainable desalination will position India as a global leader in Blue Economy R&D, fostering cutting-edge hubs and sustainable practices across sectors.

These global trends highlight the central role of science and innovation in shaping the future of ocean economies. They offer valuable insights for India as it works to build a modern, resilient, and sustainable Blue Economy. By focusing on globally validated technologies and practices, India can reduce risks, speed up progress, and position itself as a global leader in sustainable ocean development.

India's Global Positioning in Blue Economy

India's Blue Economy offers a strategic opportunity to advance national development by integrating science, technology, and research-driven solutions across key ocean sectors. With a long coastline, vast marine ecosystems, and a strong base of scientific institutions, India has the capability to lead in areas such as marine living resources, shipping, offshore renewables, and blue biotechnology. Government initiatives and missions are increasingly grounded in data, innovation, and sustainable practices. However, unlocking the full potential of these sectors will require coordinated efforts, targeted investments, and the application of cutting-edge technologies. A sector-wise approach can help identify specific opportunities where S&T can accelerate impact, improve resilience, and enhance the overall contribution of the Blue Economy to India's growth.

Table 2: Sector-wise R&D Initiatives and Impacts for Blue Economy

Sector	Key Initiatives	Key Impacts (2023–24)	Outcome
Marine Living Resources	PMMSY (INR 20,050 crore, 2020–2025, DoF): Develops IoT-based precision aquaculture systems	Deployed IoT in 1,050 fish feed plants and 320 cage culture units (DoF, 2024)	Reduced post-harvest losses by 10% through smart landing centers
	FIDF (INR 7,522 crore, DoF): Funds smart cold storage with sensor technology	Reduced post-harvest losses by 10% via 85 smart landing centers (DoF, 2024)	Increased aquaculture productivity by 15% with IoT-based systems
	Blue Revolution (INR 3,000 crore, DoF): Supports R&D in seaweed farming and mariculture tech	Established 12 seaweed tech farms and 150 mariculture projects (DoF, 2024)	Enhanced export of seaweed-based products by 5% through R&D advancements
	National Fisheries Policy, 2020 (DoF): Promotes automated fish health monitoring tech	Monitored health of 20% fish stocks with automated systems (DoF, 2024)	Improved fish health monitoring, reducing disease-related losses by 8%

Sector	Key Initiatives	Key Impacts (2023–24)	Outcome
Maritime Transport & Shipping	Sagarmala Programme (INR 5.79 lakh crore, MoPSW): Funds AI/IoT for smart port systems Maritime India Vision 2030 (MoPSW): Develops green propulsion tech R&D National Logistics Portal (Marine), 2023 (MoPSW): Advances AI-driven trade platforms Harit Sagar Guidelines, 2023 (MoPSW): Supports renewable energy tech for ports	Implemented AI/IoT in 155 port projects, achieving 1,534 MTPA capacity (MoPSW, 2024) Reduced trade processing time by 20% via AI logistics portal (MoPSW, 2024) Piloted green propulsion in 10 vessels, cutting emissions by 5% (MoPSW, 2024) 10% of ports adopted renewable energy tech, reducing emissions by 8% (MoPSW, 2024)	Reduced trade processing time by 20% through AI-driven platforms Lowered carbon emissions by 8% with green propulsion and renewable energy adoption Increased port throughput by 10%, boosting trade efficiency Enhanced export of marine manufactured goods (e.g., ship components) by 7%
Offshore Renewable Energy	National Offshore Wind Energy Policy, 2015 (MNRE): Funds offshore wind turbine R&D VGF Scheme (INR 7,453 crore, 2024, MNRE): Supports 1 GW wind tech development Deep Ocean Mission OTEC Pilots (MoES): Advances 10 MW OTEC technology Offshore Wind Assessment Guidelines, 2018 (MNRE): Develops LiDAR-based mapping tech "Integrated Ocean Energy Atlas for the EEZ of India" prepared by INCOIS	Deployed LiDAR off Gujarat, mapping 36 GW wind potential (MNRE, 2024) Sanctioned 1 GW wind projects with advanced turbines (MNRE, 2024) Initiated OTEC pilots targeting 10 MW capacity (MoES, 2024) Standardized data for 10% of EEZ renewable zones (MNRE, 2024) Estimates of renewable energy potential in the Indian EEZ	Established 1 GW offshore wind capacity, contributing to clean energy goals Advanced OTEC technology, enabling 10 MW clean energy production Improved energy security with LiDAR-based mapping of 36 GW wind potential Supported production of renewable energy equipment, increasing domestic manufacturing by 5%
Coastal Tourism & Heritage Conservation	Swadesh Darshan Scheme (INR 1,200 crore, 2014–2024, MoT): Funds AR/VR tourism tech PRASHAD Scheme (INR 300 crore, MoT): Develops digital heritage preservation tools Iconic Tourist Sites Initiative, 2020 (MoT): Integrates IoT for smart tourism Sagarmala Programme (MoPSW): Supports smart cruise terminal tech	Developed 15 coastal circuits with AR/VR, attracting 12.5M tourists (MoT, 2024) Digitally preserved 10 heritage sites, generating INR 250 crore (MoT, 2024) Deployed IoT in 12 Blue Flag beaches for ecosystem monitoring (MoEFCC, 2024) Built 5 smart cruise terminals, handling 1.2M passengers (MoPSW, 2024)	Increased tourism revenue by 12% through AR/VR-enhanced coastal circuits Preserved 10 heritage sites digitally, boosting cultural tourism by 8% Improved environmental sustainability with IoT monitoring on Blue Flag beaches Enhanced cruise tourism, contributing to INR 300 crore in economic activity
Marine Biotechnology & Blue Innovation	National Biotechnology Development Strategy, 2021–2025 (INR 2,000 crore, DBT): Funds marine biotech R&D Deep Ocean Mission (INR 500 crore, MoES): Develops bioprospecting tech for novel compounds BioRRAP Portal, 2023 (DBT): Advances digital regulatory systems for biotech Atal Innovation Mission (NITI Aayog): Supports blue tech startup R&D	Funded 15 R&D projects, identifying 200 novel compounds (DBT, 2024) Reduced regulatory processing time by 30% via BioRRAP (DBT, 2024) Supported 30 startups, commercializing 12 biotech products (NITI Aayog, 2024) Developed 10 seaweed biotech farms, boosting output by 5% (DoF, 2024)	Commercialized 12 marine biotech products, increasing exports by 6% Identified 200 novel compounds, enhancing pharmaceutical innovation Increased seaweed production by 5%, supporting sustainable material markets Streamlined biotech regulations, reducing processing time by 30%

Sector	Key Initiatives	Key Impacts (2023–24)	Outcome
Non-Living Resources	HELP, 2016 (MoPNG): Funds AI-based offshore exploration tech Deep Ocean Mission (INR 4,000 crore, 2021–2026, MoES): Develops AUVs for mineral mapping National Mineral Policy, 2019 (MoM): Promotes sustainable seabed mining tech Sagarmala Programme (MoPSW): Supports smart sensor tech for hydrocarbon logistics	Deployed 3 AUVs, mapping 30,000 km² for nodules (MoES, 2024) Awarded 28 offshore blocks with AI exploration tech (MoPNG, 2024) Developed smart sensors for 15 port projects, improving efficiency by 10% (MoPSW, 2024) Regulated 20% of offshore extraction with eco-friendly tech (MoEFCC, 2024)	Mapped 30,000 km² for placer minerals, supporting resource extraction Improved exploration efficiency by 10% with AI-based technologies Enhanced hydrocarbon logistics with smart sensors, reducing costs by 8% Promoted sustainable mining, reducing environmental impact by 20%
Ocean Climate Change Advisories	Deep Ocean Mission (INR 4,000 crore, 2021–2026, MoES): funds ocean observations and climate projections to estimate the future changes in the coastal inundation due to sea level rise, returns periods of extreme events such as cyclones, storm surges, extreme waves etc.	Deployed Argo floats, wave drifter, gliders etc to continuously monitor the changes in various ocean parameters in the climate change scenario. Developed numerical ocean models for downscaling the impacts of sea level rise, extreme waves, storms and storm surges. Deployment of underwater cabled observatory is planned.	Improved climate resilience through real-time ocean monitoring Enhanced predictive accuracy for cyclones and storm surges by 15% Supported coastal adaptation strategies, reducing inundation risks by 10% Advanced marine manufacturing for ocean monitoring equipment, boosting production by 5%

Realizing the full potential of India's Blue Economy will hinge on the strategic application of science, technology, and innovation. Across sectors, the integration of advanced research, digital tools, and frontier technologies from ocean observation systems and marine biotechnology to renewable energy platforms and smart logistics can address longstanding inefficiencies and unlock new value. India's strong institutional ecosystem, led by scientific agencies and research missions, provides a critical foundation. What is now needed is a sharper focus on translating this scientific capacity into scalable solutions, fostering innovation ecosystems, and driving collaborative R&D that links academia, industry, and coastal communities. With a science-led approach, India can future-proof its Blue Economy and emerge as a global leader in sustainable ocean development.

Vision Statement

"To empower India's Blue Economy through cutting-edge marine science and frontier technological innovations". This vision statement, aims to empower India's Blue Economy through cutting-edge marine science & services and frontier technological innovation, encapsulates the core tenets of sustainable resource utilization, ocean health, and new avenues for national prosperity. The emphasis on these elements reflects a nuanced understanding of the interconnectedness required for a truly effective blue economy. Sustainable resource utilization, leading to national prosperity, cannot be achieved without a healthy and thriving marine environment. Conversely, ensuring ocean health will not endure without addressing the economic needs and social well-being of coastal communities who depend on ocean resources. [Using resources sustainably through scientific methods can help increase India's blue trade by promoting ocean-based products in global markets. Blue products are those that either use ocean-based inputs or are designed for use in the ocean. This can help create more jobs in the ocean sector, especially through the growth of Blue MSMEs. Joint research projects can be planned with partner countries in regional groups like IORA, especially between its dialogue partners and members, to support product development or new scientific uses in the ocean sector.] The vision explicitly weaves elements which, indicate a future where economic activities are intrinsically designed to withstand environmental challenges, contribute to ecological restoration, and ensure equitable benefits for all.

Mission Statement

To provide cutting-edge S&T services for ocean observation, coastal resilience, and sustainable marine resource management; to innovate and deploy AI-driven systems, autonomous marine platforms, green maritime technologies, and marine biotechnology; and to foster global collaboration for a thriving, resilient, and inclusive Blue Economy by 2047.

Objectives

- To establish and sustain long-term ocean observation networks using autonomous underwater vehicles (AUVs), satellites, and IoT sensors to monitor marine ecosystems, coastal dynamics, and resource potential across India's Exclusive Economic Zone (EEZ).
- To develop advanced AI-driven dynamical models and data assimilation techniques for predicting oceanic and coastal phenomena, enhancing forecasting accuracy for fisheries productivity, maritime safety, and disaster resilience.
- To innovate green maritime technologies, including zero-emission propulsion systems and AI-optimized smart ports, to transform India's maritime infrastructure into a global model of sustainability and efficiency.
- To advance marine biotechnology through research into novel bio-products, such as medicines and sustainable materials, leveraging AI-assisted bioprospecting and genetic engineering for societal and environmental benefits.
- To explore and sustainably harness marine living and non-living resources using autonomous systems and high-performance computing (HPC), ensuring ecological balance and economic prosperity.
- To integrate AR/VR and IoT technologies for sustainable coastal tourism and digital preservation of marine cultural heritage, fostering inclusive growth and global tourism appeal.
- To translate marine S&T knowledge into services for societal, environmental, and economic benefits, including resilient coastal communities, renewable energy systems, and sustainable resource management.
- To foster global partnerships in marine S&T, collaborating on innovative solutions for ocean conservation, climate resilience, and resource exploration, positioning India as a leader in the global Blue Economy.
- To develop energy efficient and AI-powered fishing vessels and vessel monitoring systems for sustainable exploitation of marine fishery resources including deep sea resources
- To scale up mariculture and sea weed farming through improved mariculture technologies integrating digital systems for monitoring and control
- To promote smart seafood supply chains to minimise post-harvest losses and improved traceability
- To mitigate coastal erosion, flooding, and other climate change impacts through advanced technologies for coastal protection
- To explore robotics and AI integrated technologies for mitigating marine pollution and ocean clean- up activities
- To create innovative financial instruments for fostering the blue economy R&D

India has made significant strides in advancing its Blue Economy through robust institutional development and targeted programs. Initiatives like the Pradhan Mantri Matsya Sampada Yojana (PMMSY) have deployed IoT-based aquaculture systems, reducing post-harvest losses by 10% and establishing 150 mariculture projects by 2024. The Sagarmala Programme has transformed maritime infrastructure, implementing AI/IoT in 155 port projects and achieving a port capacity of 1,534 MTPA. The Deep Ocean Mission has pioneered AUV-based mineral mapping and OTEC pilots, while the Swadesh Darshan and PRASHAD schemes have boosted coastal tourism with AR/VR technologies, attracting 12.5 million tourists. Moving toward 2047, India plans to strengthen institutions like the National Institute of Ocean Technology (NIOT) and Indian National Centre for Ocean Information Services (INCOIS) to lead R&D in green propulsion, marine biotechnology, and blue carbon accounting. Future projects include scaling up 1 GW offshore wind capacity, deploying underwater cabled observatories for climate monitoring, and fostering global collaborations with partners like Norway, Australia, and the EU to drive innovation in sustainable marine resource management, coastal resilience, and clean energy solutions.

Strategic Goals and Roadmap

To realize the vision of empower India's Blue Economy through cutting-edge marine science and frontier technological innovations and the mission of providing cutting-edge S&T services for ocean observation, coastal resilience, sustainable resource management, and global collaboration by 2047, the following measurable goals serve as realistic stepping stones. Grounded in the Ministry of Earth Sciences' Vision 2030 and aligned with initiatives like the Deep Ocean Mission, PMMSY, Sagarmala, and National Biotechnology Strategy, these goals are clear, actionable, and tied to the mission's S&T-driven objectives, with milestones set for 2030, 2035, and 2040 to ensure steady progress towards a sustainable, resilient, and inclusive Blue Economy.

India's vision for the Blue Economy by 2047 is anchored in cutting-edge science, technology, and innovation, supported by national initiatives such as the Deep Ocean Mission, the Pradhan Mantri Matsya Sampada Yojana (PMMSY), Sagarmala, and the National Biotechnology Strategy. The measurable goals outlined in this roadmap provide a clear trajectory for sustainable growth, environmental resilience, and societal well-being.

I. By 2030, the focus is on deploying autonomous platforms AUVs, RUVs, gliders, and IoT-based ocean sensors—for real-time observation across India's Exclusive Economic Zone (EEZ), alongside AI-ML enabled predictive models for ocean state forecasting, fisheries migration, and coastal hazards in 10 coastal states. This phase also aims to equip 20% of major ports with smart systems, pilot zero-emission vessels, fund 25 marine biotechnology projects, install 5 GW of offshore wind capacity, and begin ocean thermal energy pilots. Coastal tourism will be enhanced with AR/VR in 10 tourism circuits and digitization of 15 heritage sites, while global collaboration will be strengthened through at least five international S&T partnerships. Early capacity-building initiatives include training one million coastal workers, 40% of them women, in marine S&T skills, supported by Centres of Excellence. Simultaneously, pilot projects on smart fishing vessels, climate-resilient mariculture, smart seafood supply chains, AI-based placer mineral mapping, and ocean chemical R&D will set the foundation for scale-up.

II. By 2035, India envisions expanding the observation network to estuaries and deep ocean areas, achieving 50% EEZ coverage with integrated satellite, drone, and sensor-based systems, and developing a national marine data platform powered by 10-petaflop computing capacity. AI-ML predictive systems will be extended across all coastal regions, improving resource efficiency by 25%, while 50% of ports will be transformed into smart facilities with 50 zero-emission vessels in operation. Marine biotechnology will scale up with five hubs and 25 commercial bio-products, regulatory reforms, and a 40% reduction in processing time. Offshore renewable energy will grow to 20 GW, with tidal power added. Sustainable tourism will expand to 20 Blue Flag beaches and 30 digitized heritage sites, while international partnerships will increase to 15. Skill development will scale to three million workers, generating five million jobs. In fisheries, 25% of the mechanized fleet will become smart units, mariculture will cover a quarter of potential sites, and breeding programs will expand to five new species. Smart seafood supply chains will cover a quarter of traded fish. Meanwhile, placer mineral mapping will expand to 30% of coastal zones with pilot processing plants, and chemical extraction from seawater will spread to five states. Marine Spatial Planning (MSP) will also begin, covering 30% of the EEZ.

III. By 2040, India aims to achieve 75% EEZ coverage with advanced observation systems, expand AI-ML applications to deep-sea fisheries and placer minerals, and achieve 40% efficiency in resource management. Seventy-five percent of ports will be smart and supported by 100 zero-emission vessels, including hydrogen-powered ships. Marine biotechnology will scale up seaweed-based biofuels and ocean-derived chemicals, supported by dedicated hubs. Offshore renewable energy will reach 35 GW, with gas hydrate exploration pilots underway. Coastal tourism will expand AR/VR to 20 circuits, 30 Blue Flag beaches, and integrated MSP-based planning. Global partnerships will grow to 20, co-developing at least 20 projects on ocean clean-up and coastal resilience. Capacity building will reach four million workers, 50% women, with five operational Centres of Excellence. Smart fishing fleets will comprise half of the mechanized fleet, mariculture will cover 50% of potential sites, and breeding will expand to 10 new species. Smart seafood chains will handle 40% of traded fish. Placer mineral exploration will cover 60% of coastal zones with three processing plants, while ocean chemical extraction will spread to eight states. MSP coverage will scale to 60% of the EEZ.

IV. By 2047, the ambition is to achieve 100% EEZ mapping and observation through AI-driven analytics and establish full-scale Marine Spatial Planning. AI-ML systems will be integrated across all Blue Economy sectors, improving efficiency by 50%. Every port will be fully automated, green, and AI-enabled, and 200 zero-emission vessels will operate in line with IMO standards. Marine biotechnology will deliver 50 globally competitive bio-products, making India a leader in exports. Offshore renewable energy will reach 50 GW, contributing 10% of India's clean energy mix. Coastal tourism will expand AR/VR to 25 circuits and digitize 50 heritage sites, generating INR 2 lakh crore in sustainable tourism revenue. India will lead 30 international collaborations, positioning itself as a global hub for innovation and marine S&T cooperation. Inclusive growth will empower five million coastal workers, create 10 million jobs, and ensure gender equity in skill development. In fisheries, 75% of the fleet will be converted into smart vessels, mariculture will scale up to climate-resilient systems nationwide, and smart seafood supply chains will ensure 50% traceability. Placer mineral mapping will be completed across all coastal zones with five processing plants operational, contributing 5% of global supply. The ocean-based chemical sector will become a major export pillar, contributing 10% of India's chemical exports.

Together, these progressive milestones create a clear and measurable roadmap to achieve India's Blue Economy vision for 2047, leveraging science, technology, and global partnerships to ensure sustainable growth, environmental security, and societal prosperity.

Conclusion

By 2047, India's science and technology in Blue Economy, powered by cutting-edge marine science and frontier technological innovations, will establish the nation as a global leader in sustainable ocean development, boosting economic growth, environmental resilience, and social inclusion. Through strategic investments in research and development, India will harness advanced technologies like AI-ML enabled ocean modeling, IoT-enabled monitoring systems, and marine biotechnology to modernize key sectors such as fisheries, green shipping, offshore renewables, and coastal tourism. A unified National Blue Economy Authority will coordinate efforts, integrating Marine Spatial Planning and Ocean Accounting to ensure sustainable resource use. Global partnerships with leading maritime nations will foster knowledge exchange and co-development of green technologies, positioning India as a pioneer in ocean governance. Coastal communities, including women and marginalized groups, will be empowered through extensive skilling programs, ensuring equitable access to opportunities in marine science and technology. By restoring marine ecosystems and deploying nature-based solutions like mangrove restoration, India will enhance coastal resilience against climate challenges while preserving biodiversity. A transparent monitoring framework, leveraging real-time ocean data, will track progress, ensuring alignment with national aspirations like Vision Amrit Kaal, ultimately creating a thriving, inclusive, and sustainable Blue Economy that drives national prosperity and global leadership.

Digital Communications

Ministry of Education &
Department of Telecommunications

Executive Summary

This vision document sets a national agenda to position India as a global leader in next generation digital communications (6G and beyond). It builds on India's 5G momentum—spanning deployments, indigenous stack development, and foundational research—while aligning stakeholders in technology, industry, and policy. It emphasises ubiquity, sustainability, AI native networks, security with post quantum cryptography, spectrum innovation (notably upper mid bands), and seamless terrestrial–non terrestrial integration. The document outlines global progress, India's current strengths and gaps, a clear vision, mission-aligned principles, and measurable goals with a phased roadmap through standardisation, prototyping, and trials toward 2030 and beyond.

Introduction

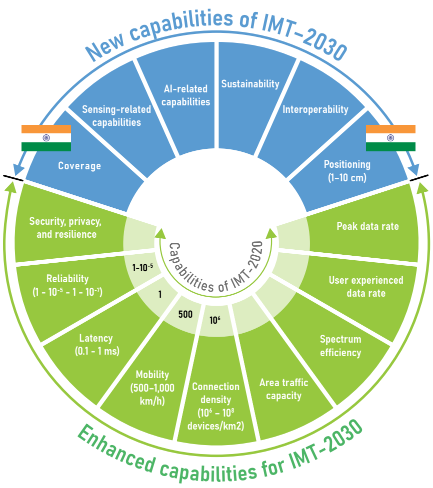
This vision document outlines a forward-looking strategy for India's advancement in 6G technology. The purpose is to align stakeholders from technology, industry, and policy towards a national agenda that positions India as a global leader in next-generation telecommunications. Now is the opportune time to create this vision due to the ongoing work on 6G globally, be it in research, standards, and products. The global standardisation process for 6G has commenced, and this vision will help us to align and be at the forefront of the ongoing developments.

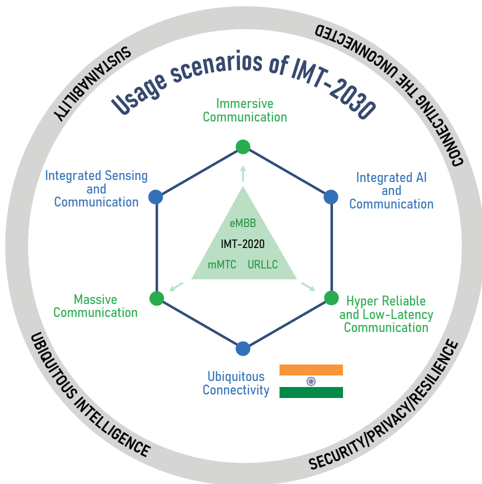
As 5G deployments mature, be it pan-India deployments of 5G, FWA (Fixed Wireless Access), indigenous stack developments, fundamental research in waveforms, multi-antenna techniques, the shift to 6G offers a chance to address lessons from 5G, such as commercial viability and geopolitical challenges. With ubiquity, sustainability, AI integration, and spectrum innovations at the forefront, this vision ensures India capitalises on emerging opportunities in a technology poised for commercialisation by 2030.

Global Scenario

Internationally, the 6G journey is accelerating, with ITU R (International Telecommunication Union – Radio-communication) defining requirements for IMT 2030 (International Mobile Telecommunication) and 3GPP (Third Generation Partnership Project) conducting studies towards developing the specifications, potentially through Release 21 by 2029.

Significant research work is being done across the world in maturing the technologies, building prototypes, identifying the spectrum, in the areas of waveforms, AI/ML for communications, integrated sensing and communications, hardware architectures, reconfigurable intelligent surfaces, and non-terrestrial networks, among a few.





There is a global debate on how 6G should shape up: should it be incremental development to 5G so that the prior investments are protected, or should it be a completely new standalone standard? Equipment vendors push for new IP rights via specification changes, while operators favour incremental upgrades from 5G to minimise hardware costs. Geopolitically, there are differing views towards open interfaces versus risking a 3GPP fork. However, in India, the upper mid band (6.425–7.125 GHz) promises contiguous 200 MHz per operator (at least) for 6G and provides exciting opportunities for the development of new products and services.

India's Global Positioning

Nationally, India stands as a bright spot in 5G, driven by deployment success, research and active participation in global bodies. In ITU R, India has contributed significantly on various topics with particular emphasis on "Ubiquitous Connectivity" scenarios, integrating terrestrial and satellite communications (SatCom) with High Altitude Platform Systems (HAPS). Contributors like WiSig, Tejas Networks, Lekha Wireless, Jio, research institutes like CEWIT, IIT Madras, IIT Bombay, IIT Hyderabad, IIT Delhi, IISc and IIT Kanpur are engaged in 3GPP, but the participation needs scaling. Challenges include limited pre-6G prototyping and patent development. India aims to build on 5G foundations, emphasising large cell coverage, energy efficiency, post Quantum Cryptography (PQC) for security, and on-device AI to enhance user experiences. Non-radio aspects like compute and network intelligence and sustainability are considered as core principles, with a preference towards lean specifications focused on commercial value.

Vision Statement

India's vision for 6G is to achieve self reliance in telecommunications infrastructure, holding up to 10% of global 6G intellectual property by 2030, while delivering ubiquitous, sustainable, and secure connectivity that drives economic growth, innovation, and digital inclusion. This encompasses enhanced mobile broadband (eMBB), massive machine type communications, and ultra reliable low latency services, extended through integrated sensing, AI optimized networks, and SatCom HAPS hybrids. By 2030+, India envisions indigenous 6G RAN (Radio Access Network) products for domestic use and exports, positioning the nation as a hub for affordable, high performance 6G solutions in emerging markets.

Mission Statement

The mission is underpinned by principles of innovation, inclusivity, sustainability, and strategic autonomy. Innovation drives the integration of foundational technologies like new waveforms, enhanced antenna systems, and AI for network optimisation, newer frequencies, ensuring 6G evolves beyond 5G's limitations. Inclusivity emphasises participation from diverse stakeholders, including young S&T leaders, startups, policy makers, industry and academia, to foster a vibrant ecosystem. Sustainability is embedded as a design principle, promoting green networks across layers to address environmental concerns and incorporate reusability. Strategic autonomy prioritises indigenous development to mitigate geopolitical risks, such as spectrum co existence and open interface debates, target India-specific use cases based on national priorities, while upholding values of security through PQC and trust in monetizable use cases.

Strategic Goals and Roadmap

To achieve this vision, a multi phased roadmap is essential. First, in the study phase (2025–2027), produce 10,000 technical submissions and 5,000 patent applications, pushing India origin features and technologies into 3GPP studies. Second, during the work item phase (2027–2029), escalate to 10,000 technical submissions and 5,000 patents, prototyping 6G base stations, core networks, and user equipment (UE), in the newer spectrum bands, with sensing and AI RAN capabilities. By standard freeze in 2029, demonstrate spec compliant field trials and secure a 10% global SEP share. Key actions include large scale funding for forming multiple "dream teams" of a few hundred experienced engineers supported by thousands of backend staff, funding national champions (MSMEs and industry) on a war footing with matching funds, and initiating these efforts within this year. Budget incorporation in FY 2025 26 and calls for anchor consortia by September 2025 will accelerate progress. IPR strategy focuses on Standards Essential Patents (SEPs) through 3GPP contributions and non SEPs for differentiated implementations, such as 6G compliant stacks, hardware elements such as analog and digital ASICS essential for developing large antenna systems and custom AI accelerators.

Measurable strategic goals are as follows:

- **Expand Standardisation Participation (2025–2027):** Increase Indian contributors in 3GPP from current levels to 20+ entities, achieving leadership in some study items (e.g., ubiquitous connectivity, waveforms, AI, and sensing), measured by the number of adopted technical documents (TDocs).
- **IPR Development Milestone (2027–2029):** File 10,000 cumulative patent applications, with 10% becoming SEPs, tracked via 3GPP agreements, aiming for 10% global share by 2029.
- **Prototyping and Trials (2025–2029):** Develop and demonstrate end to end 6G prototypes for upper mid band radios, integrated sensing, and SatCom, with successful field trials by 2029, evaluated against ITU KPIs for cell coverage, latency, and energy efficiency.
- **Ecosystem Building (Immediate-2030):** Identify and fund 5–6 national champions (2–3 macro cell OEMs, 2–3 small cell OEMs), securing matching funds and exporting indigenous gear to at least 5 international markets by 2030, measured by market share and revenue. Upgrade existing national infrastructure e.g. fiber and satellite networks, to support 6G rollouts.
- **Sustainability and Security Integration:** Ensure all 6G designs incorporate PQC and energy efficiency, achieving 20–30% better power optimisation than 5G baselines.

Conclusion

This vision document underscores the imperative of a bold 6G strategy for India, essential for economic transformation, digital equity, and global stature. By pursuing this vision through collaborative actions, innovative IPR, and sustainable innovations, India can transition from a 5G success story to a 6G powerhouse, inspiring future advancements in S&T. This framework is vital for shaping India's technological destiny beyond 2030.

Electronics and Semiconductor Manufacturing

International Advanced Research Centre for Powder Metallurgy and New Materials (ARCI) & Defence Research and Development Organisation (DRDO)

Executive Summary

Semiconductors are foundational to a hyperconnected world undergoing an AI transformation and an energy transition. The global semiconductor market is projected to cross USD 1 trillion by 2032. Recognising this, the India Semiconductor Mission (ISM) has launched an ambitious program to establish a robust semiconductor industry within the country.

This innovation-driven sector is supported globally by two essential pillars: research and innovation on one hand, and education and skilling on the other. This vision document first enumerates the strengths and weaknesses of the Indian semiconductor ecosystem across these dimensions. It then articulates a vision for India to be among the top three nations in semiconductors by 2036 — measured by research output, innovation capacity, and workforce development. Finally, it recommends specific interventions to propel India towards leadership in semiconductor research, entrepreneurship, and talent development.

Introduction

Electronics hardware, combined with software, underpins modern civilisation — from national security and industrial manufacturing to healthcare, productivity, education, and entertainment. It is at the heart of global megatrends, including AI transformation, hyperconnectivity, and the energy transition. The semiconductor domain is unique in that it is driven by a highly globalised value chain and requires continuous research and innovation to develop future technology generations, even as the current generation is still being commercialised. This document focuses on design and manufacturing aspects of semiconductor electronics, covering the full spectrum from chips to systems. Since design drives manufacturing in this sector, it is critical to address them holistically. Meanwhile, it does not address aspects such as industrial incentives, regulatory frameworks, or infrastructure in detail.

Key actors in India's semiconductor ecosystem (Ref: ITIF Report on Assessing India's Readiness to Assume a Greater Role in Global Semiconductor Value Chains, Feb 2024)

This document draws significantly from the Electronics and Semiconductor Technologies Committee of the VAIBHAV Summit 2020, which recommended, "an investment of $10B will enable India to tap into the $2T world market." This sentiment directly aligns with the announcement of the India Semiconductor Mission in December 2021.

Global Scenario

As per NITI Aayog, "the global electronics market, valued at $4.3 trillion, is dominated by China, Taiwan, USA, South Korea, Vietnam, and Malaysia." Semiconductors, the building blocks of electronics, had a global market size of about $560 billion in 2024. The global chip shortage of 2020–2023 highlighted the strategic importance of semiconductors, affecting more than 160 industries worldwide. In response, major economies have acted aggressively to bolster local and trusted semiconductor ecosystems. In addition to well-known initiatives in the US, EU, and Japan, countries such as China, South Korea, Malaysia, and Vietnam are expanding capacity and strengthening supply chains.

India's Global Positioning

The NITI Aayog report outlines a roadmap to expand India's electronics sector from $155 billion in 2023 to $500 billion by 2030. India currently exports about $25 billion worth of electronics annually – less than 1% of the global share – despite accounting for nearly 4% of global demand.

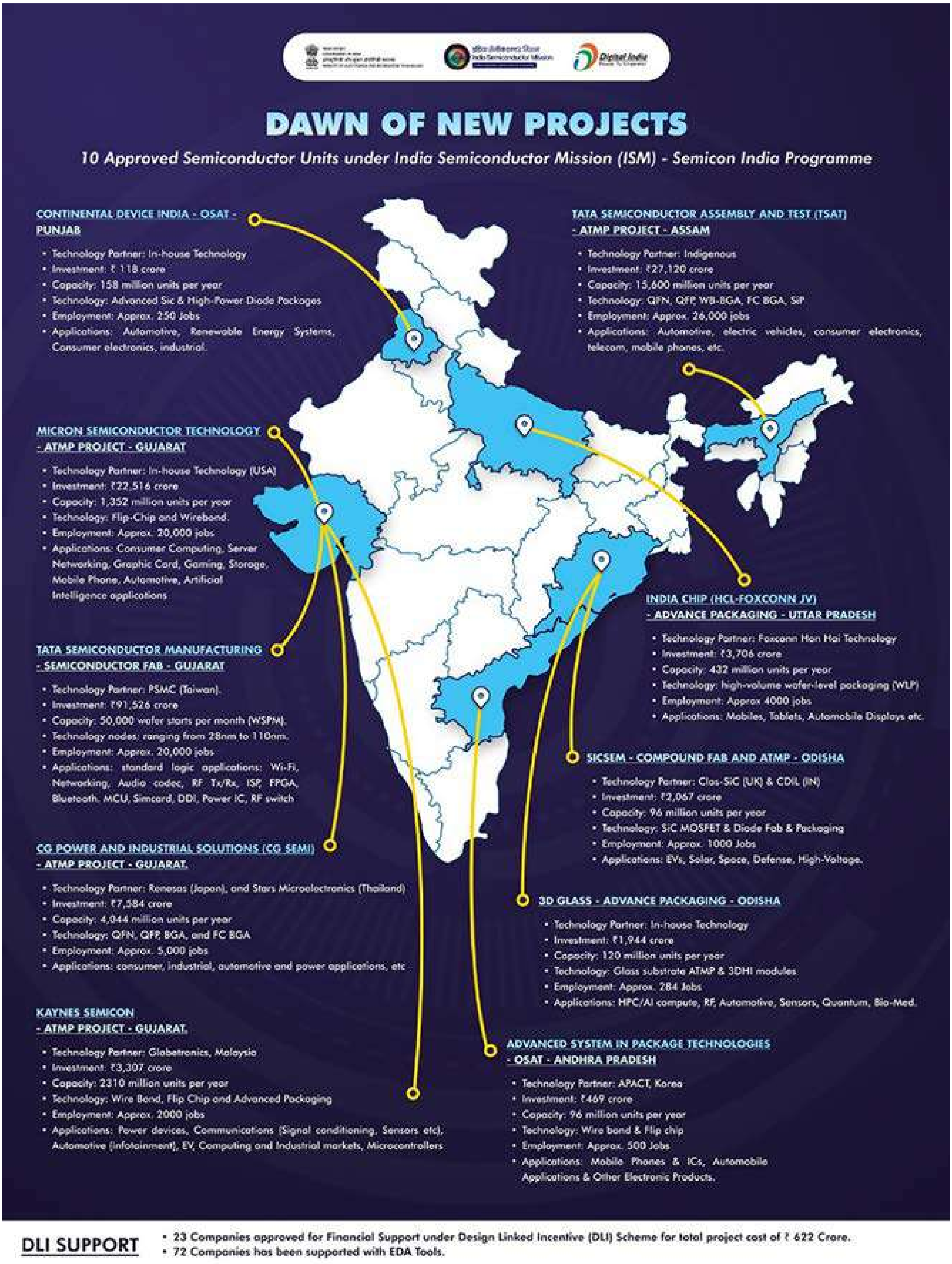
Key recommendations to improve competitiveness include localizing high-tech components, strengthening design capabilities through R&D investments and building strategic partnerships with global technology leaders.

India's key strengths in semiconductors are:

- India accounts for nearly 20% of the global chip design talent, with most major semiconductor companies operating R&D centers in the country.
- Strong centres of excellence in academia and research organizations such as DRDO, ISRO, DAE, and CSIR with decades of experience.
- Long-term funding support from agencies like MeitY, DST, MoE, DRDO, and ISRO.
- Organizations like SCL, STARC, GAETEC supporting small-volume semiconductor manufacturing for strategic applications (space and defence).
- Production-Linked Incentive (PLI) Scheme for electronics manufacturing has significantly boosted mobile phone production.
- ISM incentive scheme has kickstarted semiconductor manufacturing with multiple ATMP facilities (Micron, Tata Electronics, CG Semi, Kaynes, HCL) and a silicon fab (Tata).
- Design-Linked Incentive (DLI) Scheme is encouraging product design companies.
- C2S (Chips to Startups) program provides tool and fab access for researchers and startups.
- Nanoelectronics Centres (MeitY/DST-supported) offer fabrication facilities to academia, startups, and MSMEs.
- ISM has published a workforce development roadmap for design and manufacturing. It has also outlined a semiconductor R&D roadmap for industrial growth.
- Schemes like MoD iDEX and rising VC interest are boosting deep-tech entrepreneurship.
- DRDO's Industry-Academia Centres of Excellence foster ecosystem-wide collaboration.
- DST Technology Innovation Hubs enable thematic, nation-wide engagement.
- ANRF and the RD&I Fund are poised to boost industry-driven deep-tech R&D.
- MoE's Talent Development Initiative aims at integrated, high-level workforce planning.
- Government reforms in 2025 to improve "ease of doing research" are expected to boost productivity and efficiency.

Despite its strengths, India continues to face the following challenges:

- Few globally competitive, homegrown chip design product companies despite a large talent pool.
- Centres of excellence remain siloed and mostly at prototype-scale maturity.
- Industry investment in R&D remains limited.
- Research translation pipelines through industry partnerships are underdeveloped.
- Entrepreneurship support — both funding and patient capital — remains insufficient.
- Significant gap in industry-relevant research talent (nationally and globally).
- Shortage of hands-on manufacturing skills across the talent pipeline.



India Semiconductor Mission

Vision Statement

Position India among the top three nations in the world in electronics and semiconductor manufacturing by 2036 – measured by research, innovation, and workforce development.

Mission Statement

Parallel missions to achieve this vision:

Be top-3 globally in industry-relevant R&D output by 2036	**Be top-2 globally in industry-relevant R&D workforce by 2036**	**Be top-2 globally in skilled technical workforce by 2036**	**Be top-3 globally in aggregate startup valuation in semiconductors by 2036**

Strategic Goals and Roadmap

The strategic goal is to position India as a major player in the global semiconductor value chain.

The recommended interventions to achieve this goal are:

- Government co-funding for internal R&D programs with mandatory industry–academia collaboration.
- National challenge program for industry problems, farmed out to academia (similar to SRC or PowerAmerica) with co-funding.
- Support research translation through dedicated manpower and facilities.
- Create nationally open pilot-scale research facilities in academia and national labs.
- Build hands-on training facilities accessible to industry and academia.
- Leverage international pilot-scale facilities (TSRI, Albany Nanotech, IMEC) until domestic facilities scale up.
- National hands-on training programs from technician to PhD level, including train-the-trainers initiatives.
- Double Masters and PhD stipends to attract top talent, in line with PMRF levels.
- Attract global talent through work permit and tax incentives, especially highly skilled professionals.
- Substantially expand pre-incubation support for semiconductor start-ups.
- Dramatically increase startup funding, ensure IP localization in India, and support global IP protection.

Conclusion

India must aim to be among the top three semiconductor-producing nations by 2036, halfway to its Viksit Bharat 2047 milestone. Significant progress has already been made, but further acceleration is essential. The recommendations in this document aim to transform India into a global hub for semiconductor research, innovation, manufacturing, and talent development – positioning the country for sustained technological leadership.

Emerging Agriculture Technologies

Indian Council of Agricultural Research (ICAR)

Executive Summary

Indian agricultural production has shown consistent upward trends despite numerous challenges. However, rising concerns such as climate change, depleting natural resources, declining factor productivity, increasing population pressure, shrinking agricultural land due to urbanization, and labour shortages call for urgent reimagination of Indian agriculture. The sector must be redefined through precision farming, farm automation, genome editing, and omics technologies.

This vision document provides a focused roadmap for Emerging Agriculture Technologies (EAT), particularly in three thematic areas:

1. **Precision Agriculture**
2. **Farm Automation**
3. **Omics in Agriculture**

It outlines a path to support national priorities such as enabling climate-smart agriculture, enhancing quality production and farmers' income, promoting value addition, ensuring nutritional security and sustainability, and achieving Atmanirbhar Krishi. By integrating these technologies, India can transform its agricultural production systems – redefining how, where, and what we grow – and usher in an era of high-efficiency, climate-resilient, and nutritionally secure agriculture. The convergence of multi-omics technologies, synthetic biology tools, and controlled-environment agriculture will make Indian agriculture more precise, resilient, productive, and resource-efficient.

Introduction

Agriculture in India stands at a critical inflection point. It provides livelihoods to over half the population and ensures national food security, yet faces complex challenges – fragmented landholdings, depleting resources, climate variability, labour scarcity, and rising food demand. Simultaneously, rapid advancements in engineering, life sciences, digital technologies, and environmental systems are opening new opportunities for sustainable and inclusive transformation.

Emerging Agriculture Technologies (EAT) – encompassing smart mechanization, precision agriculture, energy-efficient solutions, post-harvest processing, natural fibre innovations, omics-based crop redesign, synthetic biology, and controlled-environment farming – together provide a multidisciplinary framework to reshape Indian agriculture. This document consolidates strategic insights across thematic pillars to create a cohesive roadmap for agricultural transformation with the aim of boosting productivity, profitability, and resilience while ensuring ecological sustainability and social inclusiveness.

Global Scenario

Precision agriculture has matured significantly in the US, Australia, Canada, and Europe, with widespread adoption of GPS-enabled machinery, VRT (Variable Rate Technology), real-time monitoring, and DSS (Decision Support Systems). Countries like the Netherlands, Singapore, Japan, and China are pioneering synthetic biology and smart farming systems, including nitrogen-fixing crops, synthetic photosynthesis pathways, and fully automated plant factories. Autonomous tractors, robotic harvesters, AI-driven grading systems, and blockchain-based supply chains are now a commercial reality in many developed nations. China operates IoT-enabled grain silos to monitor millions of tonnes of stored food in real time. Global bioeconomy investments - including bio-foundries, genome design platforms, and phenomics networks - are driving the move towards programmable agriculture, projected to exceed $1 trillion by 2030.

India's Global Positioning

India's agriculture is undergoing a positive transition driven by mechanization, technology adoption, and bioeconomy growth, but significant challenges and opportunities remain.

- Farm mechanization level in India is ~47%, with high adoption in Punjab and Haryana but very low penetration in rainfed and hilly areas.
- Government programs like SMAM and Custom Hiring Centres have improved machinery access but gaps remain.
- AI-based robotics, drones, and UAVs for precision farming are under development but not yet mainstream.

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- AI-based robotics, drones, and UAVs for precision farming are under development but not yet mainstream.
- India loses 74 million tonnes of food annually due to weak post-harvest infrastructure.
- PM-KUSUM has installed over 5.4 lakh solar pumps, but financing and maintenance remain barriers.
- India leads globally in natural fibres (jute, coir, banana fibre) and is growing its R&D in eco-friendly processing.
- The rural bioeconomy, valued at USD 165.7 billion in 2024, is projected to reach USD 300 billion by 2030.
- India possesses world-class research capabilities in genomics and molecular biology through ICAR, DBT, CSIR, etc., but synthetic biology infrastructure and regulatory frameworks are still nascent.
- Controlled-environment agriculture (hydroponics, vertical farming) is gaining traction but remains capital-intensive.
- There is a strong need to develop centre of excellence in AI, robotics, omics and precision agriculture along with centres for capacity building for precision and automatized agriculture to different stakeholders in the country.
- There is a requirement of coordinated action, long term investment and the collective will of institutions, industries and communities.

Fig 1: Variable-rate Technology for Precision Farming

Vision Statement

Position India as a global leader in sustainable, climate-resilient, and high-efficiency agriculture by 2047 through transformative deployment of engineering, biological, and digital technologies across production, processing, and distribution systems.

Mission Statement

The mission is to build a technology-driven, inclusive, and sustainable agricultural ecosystem by:

- Scaling smart mechanisation and robotics tailored to smallholder farmers
- Embedding precision agriculture and data-driven systems across all agro-ecologies
- Advancing omics and synthetic biology for next-generation, climate-smart crops
- Promoting modular plant factory systems for year-round production
- Driving renewable energy-based agro-processing and cold storage infrastructure
- Strengthening rural bio-industries via fibre innovation and circular economy models
- Establishing PPP-led innovation hubs and comprehensive skilling programs

The mission will be guided by the following strategic technological pillars:

Pillar 1: Engineering and Digital Technologies

- Affordable, modular robotics and mechanisation tools for sowing, irrigation, harvesting, and spraying
- UAV, IoT, and AI-based decision support platforms for precision input use
- Post-harvest innovations: solar dryers, decentralised cold chains, non-destructive grading, and intelligent packaging
- Micro-clusters and rural economic zones for decentralised agro-processing and job creation

Nanaji Deshmukh Plant Phenomics Centre for Precision Farming

Pillar 2: Biological Engineering and Omics

- Integration of genomics, transcriptomics, metabolomics, proteomics, and phenomics for precision breeding
- Synthetic biology for programmable crops with nitrogen-fixation, multi-stress tolerance, and high nutrient content
- Indigenous bio-foundries, gene circuit libraries, and AI-assisted breeding platforms

Pillar 3: Circular Economy and Controlled Environment Agriculture

- AI-optimized, renewable-powered plant factories and hydroponics systems for pesticide-free production
- Green fibre extraction, bio-composites, and biodegradable packaging for a circular rural economy
- Youth- and women-led enterprises as drivers of rural bioeconomic growth

Strategic Goals & Timeline

- **2025–2027:** Establish regional centres of excellence, launch pilots for precision farming, and set up fibre processing clusters and bio-innovation hubs.
- **2028–2030:** Scale modular plant factories, digitise advisory services, deploy drones across 100 districts, and expand solar post-harvest infrastructure.
- **2031–2035:** Achieve 75% mechanisation in rainfed zones, commercialise synthetic crops, and build nationwide smart farm networks.
- **2036–2047:** Position India as a global hub for agricultural synthetic biology and CEA, integrate 100% of FPOs into bioeconomy value chains, and boost exports of fibre products and synthetic crops.

Policy, institutional and capacity enablers that will drive implementation are:

- National policies for synthetic biology, drone applications, and CEA
- PPP-led deployment models for technology adoption and value-chain integration
- Large-scale capacity building for farmers, rural youth, scientists, and entrepreneurs
- Grand challenges, start-up incubators, and funding support
- Ethical, legal, and social frameworks for biosafety and data governance

Conclusion

The future of Indian agriculture lies in the convergence of technologies, disciplines, and stakeholders. EAT offers a multidimensional toolkit to engineer the next green revolution – one that is digitally intelligent, energy-efficient, biologically advanced, and socially inclusive. India already possesses the scientific infrastructure, human capital, and urgency required to lead this transformation. The creation of Centres of Excellence in AI, robotics, omics, and precision agriculture, along with targeted skilling programs, will enable widespread adoption. If pursued with commitment and coordinated action, India will not only meet domestic food security challenges but also emerge as a global model for sustainable agriculture, potentially becoming the food basket of the world.

Energy, Environment & Climate

Department of Atomic Energy

Introduction

India is on a high-growth trajectory, aspiring to reach a $30 trillion economy, which necessitates a radical and rapid expansion of its energy infrastructure. India's net zero commitment by 2070 is not a singular target but a combination of five sovereign sub-objectives: energy security, energy equity, economic development, air/water/soil enhancement, and CO2 emission reduction. Energy in an integrated sense fuels the economy both as energy (in kWh) and material (in kg / l units). And, both the process and energy part of fossil add to CO2 emissions often designated as scope 1 and 2 emissions (scope 3 is an integrated 1 and 2 for the materials sources outside the plant complex). The complexity arises because key industries—such as cement, steel, and chemicals—use fossil fuels not only for energy (Scope 2 emissions) but also as feedstocks in the process itself (Scope 1 emissions), making them "tough-to-decarbonize". The pressure is strongest on sectors with high-process emissions, demanding new technologies like Carbon Capture, Utilization, and Storage (CCUS) or fundamental process changes. Energy transition means adopting those technologies which reduce emissions from both. The BUR report gives the sectoral emissions and brings clarity on the thrust areas. Power, cement, steel, refineries, wastewater treatment, and chemicals are the sectors which need urgent solutions to reduce their CO2 emissions.

Despite having a minimal contribution to global warming, India is committed to combating climate change by pursuing a low-carbon growth strategy aimed at achieving net-zero emissions by 2070. This commitment is based on the principles of equity and Common but Differentiated Responsibilities and Respective Capabilities (CBDR-RC), as outlined in the UNFCCC.

Global Scenario

The world is collectively moving toward a net zero future, with the majority of developed nations and large emitters converging on a Net Zero target of 2050. Global average per capita GHG emission is estimated to be around 6 to 7 tonnes CO2 per year. Correspondingly, global per capita energy consumption is approximately 21,000 kWh. Whereas USA and China consume approximately 76,000 kWh and 34,000 kWh respectively. Crucially, while developed nations target a reduction in this per capita consumption, achieving universal energy access (SDG 7) requires an increase in per capita energy requirements in developing nations, highlighting a core equity challenge in the transition.

Beyond the Paris Agreement, major commitments include the goals to triple global renewable energy capacity and double the rate of energy efficiency improvements by 2030. The electrification of end-use sectors (transportation, building heating/cooling, and low-to-medium temperature industrial processes) is recognized as a cornerstone of global decarbonization. Shifting to electric power, supplied by renewable sources, creates a pathway for systemic emission reduction.

India's Global Positioning

In 2020, India's total GHG emissions, excluding Land Use Land-Use Change and Forestry (LULUCF), were 2,959 million tonnes of CO2e and 2,437 million tonnes of CO2e with the inclusion of LULUCF.

Emissions by gas:

Carbon dioxide	Methane	Nitrous oxide -	others
80.53%;	13.32%;	5.13%;	1.02%.

Emissions by sector:

Energy	Agriculture	Industrial Process and Product Use (IPPU) –
75.66%;	13.72%;	8.06%; and Waste 2.56%.

Also, in 2020, India's forest and tree cover served as a major carbon sink, absorbing approximately 522 million tonnes of CO2, which offset 22% of the nation's total emissions for that year. India has progressively continued decoupling economic growth from GHG emissions. India's forest and tree cover has consistently increased and currently stands at 25.17% of the total geographical area of the country. During 2005 to 2021, additional carbon sink of 2.29 billion tonnes of CO2 equivalent has been created.

India's GHG emissions grew by only 1.9% in 2024, and growth slowed sharply to 0.3% in Q1 2025. India's per capita GHG emissions are typically under 2.5 tonnes CO2e per year (well below the global average of 6-7 tonnes CO2e). Similarly, India's per capita energy consumption, 7,800 kWh remains significantly lower than the world average, validating the adherence to the CBDR-RC principle in international forums. However, India has achieved its 2030 Paris Agreement target of having 50% of its installed power capacity from non-fossil fuel sources five years ahead of schedule.

That India needs to secure its energy (often in the current geo-political situation it is energy independence) for its economic development in a manner that there is an economic justice or equity across the population and, an ecological balance at micro climatic levels while fulfilling the global CO2 emission reduction requirements. So, therefore India's net zero commitment is no single point destination but a combination of the five sub destinations.

Vision Statement

To secure India's future growth and ecological needs, the vision is to meet India's exponential rise in energy demand by pivoting on five fundamental elements, consisting of: 1) ample sunshine and wind, 2) abundant coal, 3) dispersed but quantifiable biomass, 4) run-of-river hydropower, and 5) nuclear energy. These will meet the objectives on Energy, Environment, and Climate (EEC), and ensure India's energy security, energy equity, economic development, air, water, and soil enhancement, and CO2 emission reduction as our sovereign principles to meet the energy-environment challenge.

The above is a mix of renewable energy resources and nuclear energy as the ultimate source of energy in abundance (beyond 2070) and fossil fuels (coal) with CCUS acting as a bridge. India's pursuit on CCUS is critical as a buffer to meet our energy needs and climate change obligations. CCUS, which stands for CO2 capture, utilization, storage, and sequestration, forms a key link for the next few decades until nuclear energy will be able to replace coal as we reach a plateau in our energy demand beyond 2070.

Mission Statement

To fulfil the vision statement, the core will be Science and Technology and a quadruple helix model (academia-industry-startups-government) to rapidly accelerate technology deployment while protecting investments from technological obsolescence. The disruptive nature of developments in EEC necessitates a flexible approach in policy and regulatory frameworks to ensure the quick absorption of new technologies. The seven mission statements are given below:

1. By 2047, India plans to meet its energy demand by leveraging five key resources. The strategy focuses on developing new technologies and aims for a total energy supply of 28,000 TWh. Of this, 13,500 TWh will come from renewable sources: 10,500 TWh based on the maximising the available land mass and high efficiency based solar-wind power plants, 3,000 TWh from various biomass sources, including agricultural and municipal waste. 2,000 TWh will come from hydropower projects. To fill the remaining 12,500 TWh deficit, will be supplied by coal, requiring the development of Carbon Capture, Utilization, and Storage (CCUS) to mitigate emissions and by nuclear energy. The plan also includes using Direct Air Capture (DAC) technologies to remove approximately 180 billion tons of CO2.
2. India must pursue a comprehensive and inclusive approach to its energy future by advancing clean coal technologies using coal gasification to produce cleaner fuels. Development of CO2 capture-ready new technologies. The nation has already demonstrated its capability with a successful large-scale pilot plant in Pune, showcasing India's "make in India" initiative and its ability to develop zero-emission technology for high-ash India's coal (supported by Niti Aayog and DST). Critically, this technology integrates CCUS to capture and reuse CO2, and convert to methanol making this a zero-emission plant.
3. Nuclear energy is a key player in meeting India's EEC objectives, so we must push the technological lever in this area. Rapid addition of large reactors besides Small Modular Reactors (SMRs). The three-phase nuclear program needs to ensure the early introduction of thorium into the nuclear fuel cycle. Thorium-based SMR, or its integration into our Pressurized Heavy Water Reactors (PHWRs), is the most easily adaptable solution for India.
4. All new technologies should ensure that India does not fall into the trap of a restricted supply chain, especially in the field of non-earth abundant materials RE-PMG-Li- CO/Ni-Graphite etc. This requirement must be built into the early stage of any technology deployment plan for the country.
5. To avoid becoming a dumping ground for second-rate technology, India must prioritize speed and scale in its "Make in India" initiatives. To facilitate rapid deployment, the government must provide strong support through favourable policy instruments and flexible regulatory frameworks. Public opinion and advocacy are also critical for the safe and effective deployment of new technologies.
6. The core of EEC technologies relies on synthesizing new, disruptive materials like perovskites, graphene, and specialized catalysts. The global race to discover and patent these materials is driven by modern tools, including molecular-level modeling, Artificial Intelligence and Machine Learning (AIML), and robotic experimental setups. India needs a large-scale material synthesis centre, supported by the Anusandhan National Research Foundation (ANRF), to remain competitive in this field and secure its intellectual property.
7. Life Cycle Analysis: The mission statement for faster deployment of cleaner energy technologies needs to have LCA as an integral part of the development.

Strategic Goals and Roadmap

A. Energy Supply Targets by 2047 (Total Demand ≈28,000 TWh)

Energy Source	Target (TWh)	% of Total Demand	Notes
Renewable Energy (RE)	10,500	37.5%	Solar and Wind, maximizing land and efficiency.
Biomass	3,000	10.7%	From agriculture, forestry, industrial, and municipal waste.
Hydro Power	2,000	7.1%	Run-of-river, with reduced gestation periods.
Coal	10,000	35.7%	Doubling consumption, but share drops from 62% to 42%. Requires 2 BT of CO_2 removal via CCUS.
Nuclear	2,500	8.9%	Aggressive ramp-up (over 100 GW capacity).

B. The nine levers that will feed into our energy roadmap:

1. **Faster penetration of RE – Solar and Wind:** Focus on increasing efficiency and adopting new materials like perovskite with Gallium nitride, quantum dots, and graphene, and perovskite-based tandem solar cells (c-Si and CIGS). For wind, faster deployment by repurposing existing turbines and harnessing offshore wind potential. Additionally, India should explore geothermal energy in regions like Leh Ladakh, the SONATA (Sona, Narmada, Tapi) belt, and Western India hot springs.
2. **Energy storage technologies:** Energy storage with options ranging from rechargeable batteries and flow batteries to hydrogen, pumped hydro, and compressed air storage. To ensure independence and sustainability, India must prioritize developing storage technologies that utilize abundant, domestically available materials rather than depending on imported, non-earth abundant resources like lithium, cobalt, and nickel.
3. **Circular economy:** Circular economy model based on the philosophy of "more from less for more and more people", with principle of boosting efficiency in all processes.
4. **Biomass:** A Plan to accurately estimate all biogenic resources. An integrated biomass mission is essential to develop India-specific technologies that efficiently convert biomass into fuels and materials for co-firing, gasification, ethanol production, biogas, hydrogen, and sustainable aviation fuels, thereby reducing the country's dependence on imported oil and gas.
5. **Hydrogen and hydrogen-based energy systems:** Developing a full-scale hydrogen ecosystem, from production and storage to transmission and end-use applications for reaching annual hydrogen production from 5 MT by 2030 to nearly 150 MT by 2047, as per our target under the National Green Hydrogen Mission (NGHM). India's strategy includes a unique hydrogen valley concept, with four zones planned across the country. An example is the Jodhpur Hydrogen Valley at IIT Jodhpur, which aims to produce 350 TPA for use in mobility, gas blending, and as a substitute for LPG in industrial applications.

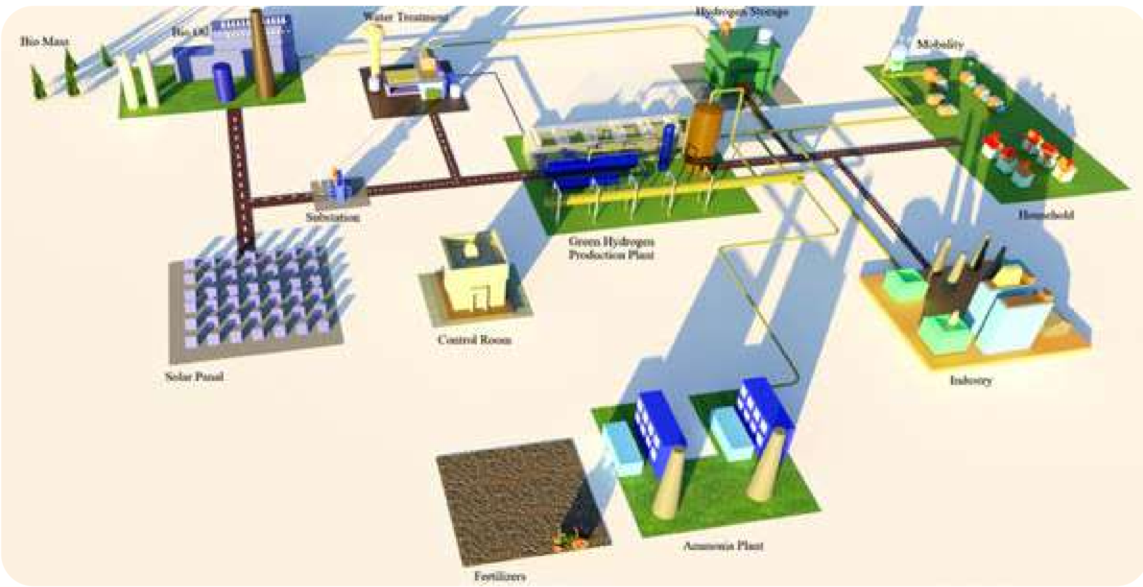


Figure 1. Conceptual diagram of the Hydrogen Valley at IIT Jodhpur, illustrating the complete hydrogen ecosystem from generation to transport.

6. **Faster penetration of e-mobility on batteries and hydrogen:** A multi-modal approach powered by indigenous green electricity and green hydrogen.

7. **Modern agriculture Greening the Fields:** Developing sustainable Energy Strategies for Agriculture, Irrigation, and Cold Chains. By integrating renewable energy, precision farming, using IoT sensors and drones, drip irrigation and smart irrigation systems, solar-powered refrigeration in on-site storage facilities and by turning agricultural waste into a resource on the farm.

8. **CCUS and natural climatic solutions:** A three-pronged approach for CCUS:

Strategy #1

The current state-of-art technologies in CCUS to be integrated as end-of-pipe solution EOP to the existing CO2 emitting industries.

Strategy # 2

The next state-of-art technologies in CCUS to be integrated with the CCUS compliant design CCD in the CO2 emitting industries.

Strategy # 3

Advanced technologies for making of cement, steel, aluminium, power, fertilisers, refineries, chemicals using new materials exhibited as photo-bio-electro-catalytic conversions and doing CCUS in a one pot, COP.

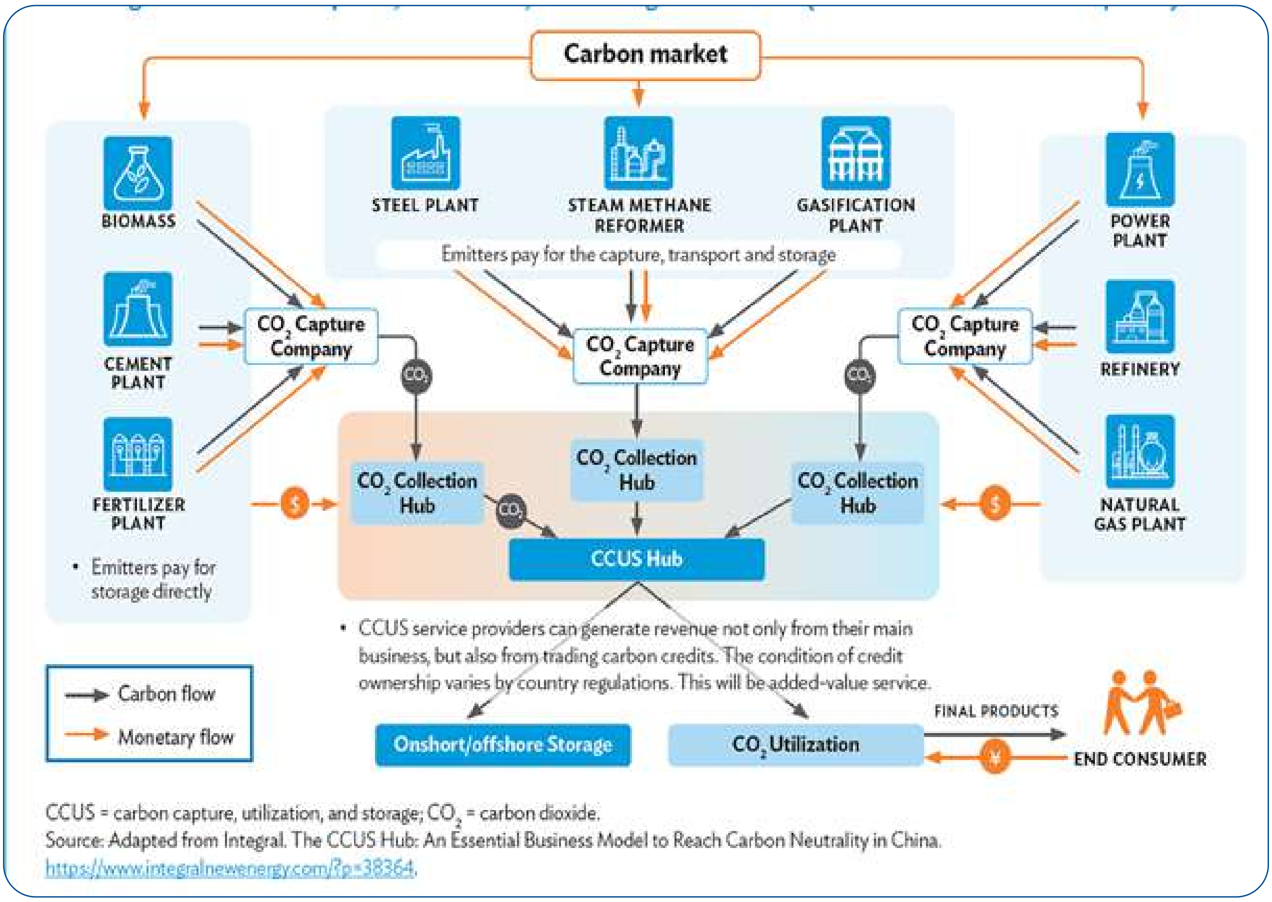


Figure 2. Conceptual "Hub-and-Spoke" model for India's future CO_2 capture and storage.

9. **Nuclear energy:** Scale up nuclear energy capacity to 100 GW by 2047, a more than tenfold increase from the current nuclear energy capacity of 8.88 GW, under Nuclear Energy Mission. An ambitious plan central to the country's strategy for achieving energy security and climate goals by providing a reliable base load power source to replace coal.

Key Components of India's Nuclear Stratezgy:

- Indigenous Reactors: The core of the strategy is the rapid, large-scale deployment of indigenously developed 700 MW Pressurized Heavy Water Reactors (PHWRs). These will be deployed in a "flee t mode" by organizations like NPCIL and through joint ventures such as ASHVINI with NTPC.
- Small Modular Reactors (SMRs): A budget of ₹20,000 crores has been allocated to develop at least five SMRs by 2033. India is also redesigning its 220 MW PHWR as a Bharat SMR to serve industrial captive power needs in remote areas.
- International Collaboration: To accelerate capacity addition, India is also considering proven foreign Pressurized Water Reactor (PWR) technologies, with a target of adding 30 GW of capacity from these reactors.
- Future Technologies: R&D is underway for advanced reactor technologies, including fast breeder reactors, which are expected to contribute 5 GW by 2047. India is also exploring innovative fuels that can utilize its vast thorium reserves, creating a pathway for direct use of this resource.

Conclusion

India is at a high growth phase trajectory, and we need to grow near double digits to reach the 30 trillion $ mark. We must still build 80% of India in next two decades and that is going to be a tough challenge. The energy transition is a great opportunity to develop technologies based on deep science that is unleashing in the form of discovery of new materials and devices. This needs a strong energy start-up ecosystem which works at the cutting edge between academia and research institutions on one hand and the industry on the other. The quadruple helix of academia-deep tech incubators – industry and the policy makers. India needs speed and scale in our development as the Cost of Lag Introduce the concept of "Technological Debt" (parallel to financial debt). "You cannot leap into the future with legacy systems. Technological sovereignty for India is not optional—it's existential "

To build a new technological land scape which can replace the existing one in energy-environment and climate (as given in the roadmap illustrated above), India needs a radically different eco system to ensure that the core technologies are built in India and its benefits percolates to all strata of society. This is a great opportunity for young India to build a new and Viksit Bharat@2047!

Health & Medical Technologies

Department of Health Research (ICMR) and Ministry of Ayush

Executive Summary

India stands at a transformative juncture in its healthcare landscape, propelled by rapid advancements in health and medical technologies. The integration of innovative solutions such as digital health, telemedicine, artificial intelligence (AI), and data analytics presents a unique opportunity to enhance health outcomes, optimise resource utilisation, and strengthen health systems nationwide. India has made strategic investments by prioritising health funding within national budgets, establishing dedicated innovation funds, encouraging public-private partnerships, strengthening health administration, and initiating regulatory frameworks. These steps have accelerated technology adoption, improved health outcomes, and contributed to socioeconomic development.

Integrating health technology funding into schemes like Ayushman Bharat and the National Digital Health Mission (NDHM) can further catalyse large-scale digital transformation, laying a foundation for a resilient, inclusive health system. The primary purpose of this vision document is to create a comprehensive roadmap for integrating health and medical technologies into India's healthcare system, aligning with the national goal of achieving Viksit Bharat by 2047.

Introduction

Health and medical technologies are among the fastest-growing sectors, encompassing a wide range of innovations in healthcare procedures, pharmaceuticals, medical devices, digital solutions, and AI-powered diagnostics. Globally, healthcare is becoming increasingly data-driven, with AI and telemedicine now being essential components of modern health systems. The Food and Drug Administration (FDA) has authorised numerous AI-driven medical devices, indicating growing trust in such technologies. Beyond AI, technologies such as the Internet of Things (IoT) and blockchain are entering healthcare, though challenges of scientific validation and regulatory alignment remain. Global interest in Ayush systems is increasing, with India partnering with World Health Organization (WHO) to establish the Global Traditional Medicine Centre, though regulatory challenges persist.

Robotic surgery, telemedicine, remote monitoring, additive manufacturing (bio-printing), genetic engineering, and wearable sensors have revolutionized healthcare by enabling personalized medicine, innovative surgical procedures, and affordable diagnostics and implants. Placing India as a global leader in health and medical technologies will require an emphasis on indigenous biomedical innovations and Ayurveda, Yoga & Naturopathy, Unani, Siddha, and Homeopathy (AYUSH) healthcare systems. The goal is to transform India into a worldwide leader by establishing a robust, inclusive, and technologically advanced healthcare ecosystem, adopting the One Health Approach and early Health Technology Assessments (HTA) to create an integrated health delivery system.

Global Scenario

The global health and medical technology sector is evolving rapidly, driven largely by digital innovation. The global medical devices market was valued at $542.21 billion in 2024 and $572.31 billion in 2025, and is projected to grow to $886.68 billion by 2032. Key players such as Medtronic, Johnson & Johnson, Siemens Healthineers, GE Healthcare, and Boston Scientific are investing in R&D to develop novel equipment. Advances in AI, ML, and imaging technologies are enabling quicker diagnoses and personalised treatment. Telemedicine has expanded access to healthcare, particularly in underserved areas and during crises. Genomics and precision medicine allow customised therapies, while robotics improves surgical efficiency and hospital logistics.

Digital health records and interoperable systems are improving integration, though data privacy and security remain major challenges. AI-assisted drug discovery and clinical trial design promise to reduce costs and timelines. 3D printing is enabling custom implants, prosthetics, and tissue models. Regulators worldwide are striving to balance patient safety with quick access to innovative therapies. High-income countries lead adoption, while lower-income regions face cost and infrastructure barriers. The FDA has recently approved a record number of AI/ML-enabled medical devices, with the highest approvals in radiology, followed by cardiology and neurology.

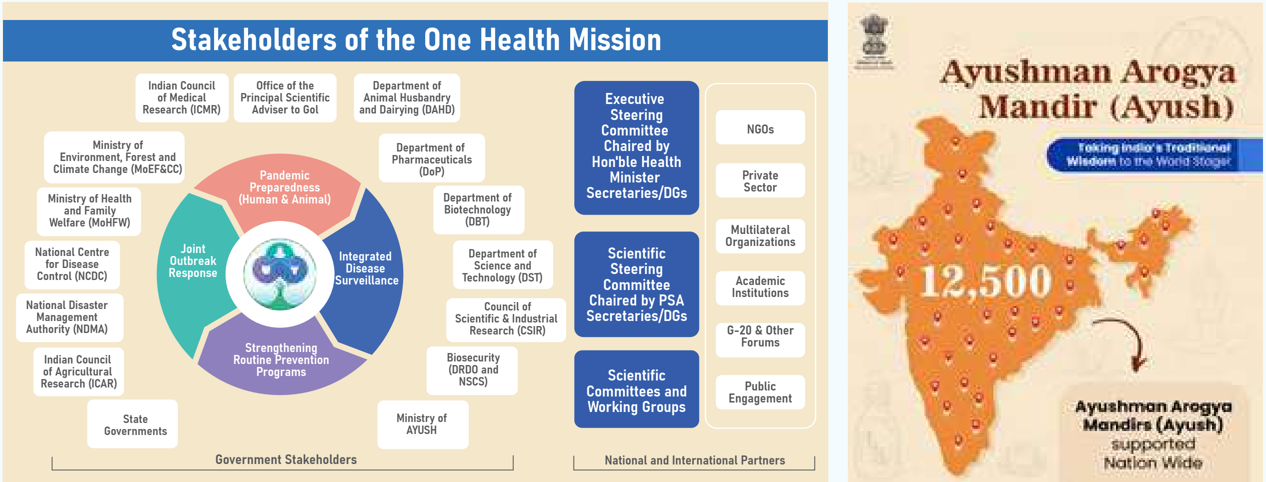
India's Global Positioning

India's healthcare landscape shows significant progress alongside persistent challenges. Health and medical technologies are now recognized as a sunrise sector. India is simultaneously advancing modern medical technologies (pharmaceuticals, medical devices, diagnostics, AI solutions) and traditional systems (Ayurveda, Yoga and Naturopathy, Unani, Siddha, Homeopathy – AYUSH). Medical tourism has grown substantially, and exports of medical devices are increasing, supported by innovation, cost-effective production, and proactive government initiatives such as Make in India.

Despite progress, challenges remain:

- Tier 1 cities have world-class hospitals and attract ~5 lakh medical tourists annually, but quality and accessibility gaps persist.
- Rural areas, home to 70% of the population, face severe shortages: 75% of dispensaries, 80% of doctors, and 60% of hospitals are urban-centric2
- Diagnostic facilities are scarce outside urban areas.
- Healthcare costs are rising, while the disease burden shifts to chronic lifestyle disorders.
- By 2047, 20% of India's population will be over 60, straining health systems.

The National One Health Mission focuses on building cross-sectoral collaboration, developing a national network of high-risk pathogen labs (BSL-3/4), and creating rapid-response tools (AI, NGS, metagenomics pipelines, plug-and-play vaccine platforms). 12,500 wellness centres and Ayushman Arogya Mandirs have been established to bring quality AYUSH care to all parts of the country.



Stakeholders of One Health Mission and Ayushman Arogya Mandir, established for bringing quality care through Ayurveda, Yoga, Unani, Siddha and Homoeopathy.

Vision Statement

By 2047, India will emerge as a global leader in accessible, affordable, and innovative health technologies.

The goals include:

- Establishing India as a global leader in health and medical innovations
- Transforming India's healthcare system using digital health for accessible, affordable, evidence-based care
- Positioning India as an exporter of indigenous biomedical technologies, including devices and implants
- Building a resilient, inclusive, and technologically advanced healthcare ecosystem
- Leveraging AI in medical devices, pioneering vaccine development, and adopting the One Health approach
- Enhancing quality of medical education through skills training, multidisciplinary integration, and global alignment
- Establishing protocols and standards for medical device testing
- Mainstreaming AYUSH as a validated healthcare innovation by 2047

Mission Statement

Fostering innovation, strengthening regulations, building capacity, and promoting collaboration to position India as a global health-tech leader.

Focus areas include:

- Strategic funding, research support, regulatory excellence, and policy frameworks
- Public-private partnerships, telemedicine integration, and digital health infrastructure development
- Encouraging interdisciplinary R&D in biomaterials and biomedical devices
- Strengthening domestic manufacturing and developing medical device parks
- Collaboration between academia, industry, and clinicians for translational research
- Integration of digital technologies into medical education and training
- Development of policies, regulations, and skilling programs to accelerate adoption
- Establishment of innovation hubs and R&D centres for AI-enabled devices, pharmaceuticals, and vaccines
- Strengthening regulatory systems, surveillance, and cross-sector collaboration for One Health
- Strengthening AYUSH education, standardizing drug quality, and building preventive healthcare models

Strategic Goals and Roadmap

(i) Promote innovation and research ecosystems:

a) Foster indigenous innovation and manufacturing, supporting Atma-Nirbhar Bharat in Medicine, MedTech, and BioTech
b) Support startups and MSMEs to bring solutions to market and collaborate with large industry
c) Develop affordable, portable, AI-integrated health solutions for underserved areas
d) Create integrated One Health monitoring platforms
e) Establish holistic health centres with evidence-based AYUSH protocols

(ii) Foster funding and policy support:

a) Invest in domestic industry, strengthen infrastructure, and promote local device manufacturing
b) Develop novel, affordable biomaterials and devices from indigenous resources
c) Facilitate translational research through industry–academia–clinician collaboration

(iii) Capacity building and skill development:

a) Build skilled human resources in AI, biomaterials, electromechanics, and health sciences
b) Train R&D, manufacturing, and business development professionals
c) Establish IP and incubation cells in medical institutions and integrate digital technologies into curricula
d) Disseminate policy information widely
e) Introduce dual-degree programs (medicine + technology)

(iv) Enhance digital health infrastructure:

a) Build integrated health stacks and deploy telemedicine services
b) Develop indigenous cybersecurity tools and AI fraud prevention programs
c) Invest in blockchain, big data analytics, quantum computing, and precision public health

(v) Strengthen health governance and regulation:

a) Create a sustainable funding environment
b) Streamline approval and certification processes to align with global standards
c) Establish a hub-and-spoke model for innovation incubation

Conclusion

Collaboration between government, academia, industry, financial institutions, and civil society will be essential to achieve this vision. Focusing on indigenous innovation, grassroots deployment, regulatory excellence, strong PPPs, and capacity building will ensure India's healthcare sector becomes self-reliant and globally competitive. By implementing effectively, India can position itself as a leader in health and medical technologies by 2047, providing equitable, high-quality care for all citizens.

Quantum Science & Technology

Department of Science & Technology

Executive Summary

Quantum Science and Technology (QST) marks a paradigm shift in computing, communication, sensing, and materials engineering, with transformative applications in national security, healthcare, energy, finance, and environmental monitoring. Estimates suggest that by 2035, these technologies could generate between $1 trillion and $2 trillion of new value across industries. Through the National Quantum Mission (NQM), India has made early investments to transform research excellence into sovereign capability and economic opportunity. By bridging gaps in infrastructure, talent, and translational pathways, the mission envisions India to become a dominant player in the global quantum landscape, controlling critical parts of the supply chain, particularly in quantum sensors, computing, and quantum-safe cryptography.

Introduction

Quantum technologies are expected to be among the most transformative advancements of this century, with the potential to revolutionise multiple sectors such as healthcare, materials science, climate research, finance, and logistics. Built on the principles of quantum physics, these technologies are classified into four key vectors. Quantum computing harnesses quantum bits (qubits) to perform exponentially faster computations than classical computers, enabling breakthroughs in complex problem-solving such as simulating nature, optimisation, machine learning, and cryptography—while also posing the potential to break widely used RSA encryption. Quantum communication employs quantum key distribution and entanglement to achieve ultra-secure communication resistant to eavesdropping, crucial for safeguarding government and defense communications. Quantum sensing and metrology use quantum mechanical effects for highly precise measurements, as demonstrated by atomic clocks and magnetometers, offering strategic advantages in defense, aerospace, and space exploration. Quantum materials leverage unique quantum properties to create novel materials and devices that underpin advancements in the other quantum domains. Although still in its early stages, the field holds immense strategic value, driving a surge in global investments. For India, leadership in quantum is a strategic imperative—vital for safeguarding technological sovereignty through indigenous infrastructure and intellectual property; enhancing national security via ultra-secure communications and post-quantum cryptography; catalysing economic growth by fostering high-value industries in computing, sensing, and materials; and advancing scientific excellence through pioneering, cross-disciplinary research.

Global Scenario

The last decade has witnessed a rapid acceleration in quantum R&D worldwide, as nations position themselves for leadership in this critical technology domain. Governments, academia, and industry are converging to create integrated quantum ecosystems, supported by large-scale funding, dedicated research hubs, and cross-border collaborations.

Global investment in QST is accelerating worldwide, driven by major national and international initiatives. These include the U.S. National Quantum Initiative, supported by Department of Energy (DOE)-led national laboratories; the EU Quantum Flagship, which integrates technology development with commercialization support; China's quantum satellite network and national cryptography strategies; and the QUAD Quantum Center of Excellence, which fosters collaboration among India, Japan, Australia, and the United States.

Leading global players such as IBM, Google, Microsoft, and a range of emerging startups from the USA, Germany, the UK, China, Canada, India, Japan, and Australia are advancing quantum computing, communication networks, and sensor technologies. Investment in national quantum (NQ) initiatives ranges from around $0.5 billion in countries like Qatar to approximately $15 billion in China, the highest in the world.

The designation of 2025 as the International Year of Quantum Science and Technology further amplifies global focus, fostering coordinated public engagement, educational outreach, and international collaboration. This creates an unparalleled window for India to align its quantum initiatives with global momentum, not as a catch-up exercise, but as an opportunity to co-lead in shaping the standards, applications, and ethics of quantum technologies worldwide.

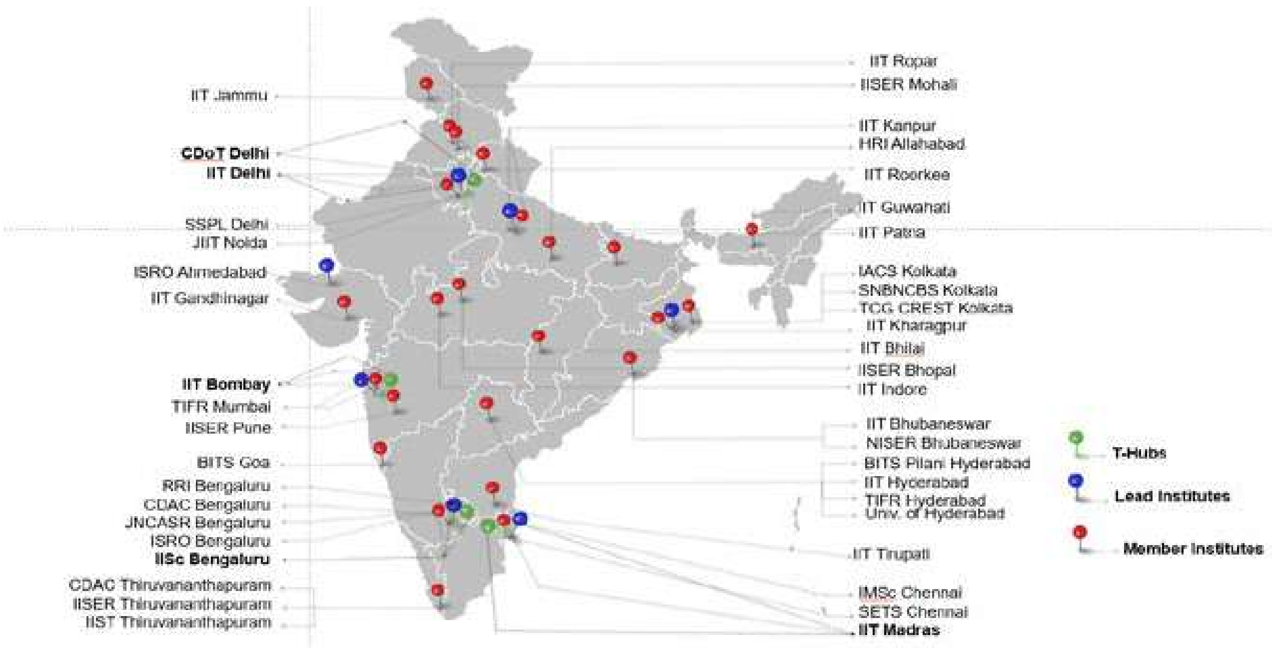
India's Global Positioning

The Indian government launched the National Quantum Mission (NQM) in April 2023, allocating approximately ₹6,003.65 crore (around $730 million) for a period of eight years. The National Quantum Mission launched four Thematic Hubs in four technology verticals on 30th September 2024 to strengthen India's position as a global leader in quantum technology, namely (i) Quantum Computing-Thematic Hub: IISc, Bengaluru is leading R&D towards developing 1,000-qubit quantum computers within eight years, (ii) Quantum Communication-Thematic Hub: IIT Madras, in association with C-DoT, is focusing on satellite and fibre-optic quantum communication systems. (iii) Quantum Sensing and Metrology-Thematic Hub: IIT Bombay is working on ultra-precise quantum sensors and measurement tools, and (iv) Quantum Materials and Devices-Thematic Hub: IIT Delhi is advancing the development of quantum materials and devices for diverse applications. The Hub–Spoke–Spike framework unites 152 researchers across 43 academic and R&D institutions, enabling collaborative technology development, capacity building, entrepreneurship, and international engagement. Ambitious targets include fostering at least 10 quantum startups, each generating over $100 million in cumulative revenue and capturing more than 50% of the global quantum software market value.

Before the launch of the National Quantum Mission, India had already laid a strong foundation for quantum technology research. The Department of Science and Technology (DST) initiated the Quantum Enabled Science and Technology (QuEST) program in March 2019, supporting 51 projects at a total cost of ₹186.95 crore. It also established a Technology Innovation Hub (TIH) in Quantum Technologies at IISER Pune in October 2020 under the National Mission on Interdisciplinary Cyber Physical Systems, and enabled autonomous institutes such as RRI Bengaluru, JNCASR Bengaluru, and S. N. Bose Kolkata to initiate dedicated quantum technology programs.

NQM has also supported eight quantum startups by providing venture capital, intellectual property support, and facilitating market access, leading to major milestones.

India benefits from a large scientific community, producing around 91,000 quantum-relevant graduates each year, and a strong software and engineering base, with IT companies developing internal Centres of Excellence. There is also high engagement with internationally available cloud quantum systems, reflecting rising awareness and training across both academic and industrial stakeholders.



Mapping of institutions under 4 T-Hubs comprising 14 Technical groups and 17 project teams

Vision Statement

By 2047, India envisions transforming into a truly quantum-powered economy, emerging not just as a contributor but as a global leader in the quantum technology ecosystem. This leadership will be defined by a commanding presence in the global quantum supply chain, with particular strengths in quantum sensors, quantum computing, quantum communication and quantum-safe cryptography, and quantum materials and devices. Beyond technological adoption, India aims to become a hub for groundbreaking scientific discoveries in quantum science and engineering, driving innovation that shapes the future of the field. This ambitious goal lays the foundation for realizing the broader national aspiration of Viksit Bharat@2047. Achieving this vision demands decisive action over the next decade—through coordinated investments, accelerated creation of intellectual property, and bold, synergistic partnerships between academia, industry, and government.

Mission Statement

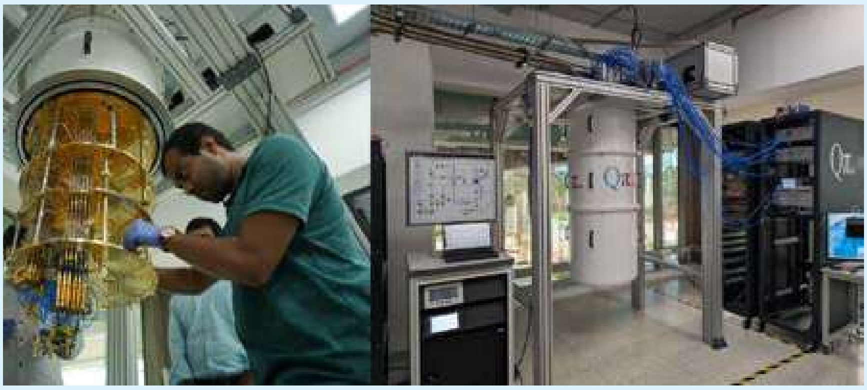
India's mission to build a true quantum-powered economy and realise the vision of Viksit Bharat by 2047 is ambitious, multidimensional, and rooted in decisive action across key strategic areas:

- Build a world-class quantum workforce and research ecosystem: Develop a strong pipeline of talent across academia, startups, and enterprises by expanding expertise in scientific research, deep engineering, and techno-business skills across all quantum verticals. This will ensure India remains at the forefront of foundational scientific breakthroughs.
- Catalyse industry engagement and private investment: Drive large-scale participation from industry and stimulate private capital flow to accelerate the commercialisation of quantum technologies. The goal is to create a vibrant ecosystem of at least 10 quantum breakthrough startups.
- Lead the global quantum software and algorithms market: Leverage India's strong IT services base to capture over 50% of the global quantum software market value, focusing on algorithm development, middleware, cloud platforms, and hybrid quantum-classical tools.
- Deploy quantum technologies at scale: Integrate quantum solutions into strategic and high-impact sectors such as defense, oil and gas, healthcare, and finance. This includes mainstream adoption in public sector enterprises and embedding quantum technologies into mission-critical systems.
- Achieve quantum Atmanirbharta: Position India as a net exporter of quantum hardware and software, gain control over critical nodes of global supply chains, and ensure India-made quantum components are globally recognised and interoperable.
- Lead in global standards and partnerships: Take an active role in setting international quantum standards and building trusted partnerships to ensure seamless global market access for Indian quantum products and establish India as a reliable provider of secure and ethical quantum solutions.

Strategic Goals and Roadmap

The National Quantum Mission (NQM) is building a robust quantum ecosystem through a time-bound roadmap of initiatives and milestones, aimed at advancing India's capabilities and global leadership in the field. The mission objectives include developing intermediate-scale quantum computers with 50-1000 physical qubits within 8 years across various platforms, such as superconducting and photonic technology. Satellite-based secure quantum communications between ground stations over a range of 2000 km within India, long-distance secure quantum communications with other countries, inter-city quantum key distribution over 2000 km, as well as multi-node Quantum networks with quantum memories are also some of the deliverables of the mission. The NQM will focus on developing magnetometers with high sensitivity in atomic systems and atomic clocks for precision timing, communications, and navigation. It will also support the design and synthesis of quantum materials such as superconductors, novel semiconductor structures, and topological materials for the fabrication of quantum devices. Single photon sources/detectors, and entangled photon sources will also be developed for quantum communications, sensing, and metrological applications.

The startup QpiAI has launched QpiAI Indus, a 25-qubit superconducting quantum computer integrating advanced processors, Quantum-HPC software, and AI-driven quantum solutions and the startup QNu Labs has introduced QShield, the world's first unique quantum security platform, along with a quantum-safe communication chip module.



QPiAI Indus (25 Qubit Quantum Computer) at Bengaluru

Conclusion

India stands at a pivotal moment to build a robust quantum ecosystem with the potential for profound national impact and global leadership. This effort is crucial for enabling the broader aspiration of Viksit Bharat by 2047. Achieving these demands requires decisive action: expanding and upskilling the quantum workforce, catalyzing private investment, accelerating lab-to-market transitions, fostering entrepreneurial risk-taking, retaining deep-tech startups in India, leading in global standard-setting, and strengthening trade relations. With bold execution, India can position itself as a quantum leader, driving innovation, economic growth, and strategic self-reliance by 2047.

Space Technologies

Department of Space

Executive Summary

The "Viksit Bharat@2047" vision aims for comprehensive socio-economic advancement by the time of India's centenary of independence in 2047. This vision encompasses economic growth, social progress, environmental sustainability and good governance, with science and technology as key catalysts. Towards this, India's space program also plays a crucial role in achieving the nation's "Viksit Bharat" vision by 2047, driving technological innovation, economic growth and societal benefits. Space technology is a key driver of innovation, contributing to advancements in various fields. Aligning with global sustainability goals, technological innovation supports India's vision of becoming a developed nation by 2047. The focus is on the self-reliance and indigenous capability development and align with the national development goals. At the same time, space derived products and services will be creating job opportunities and positively impacting local economies.

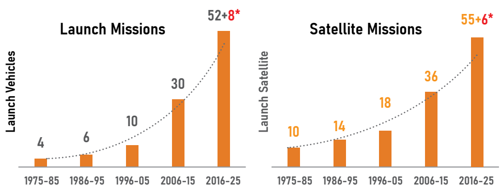
Introduction

- India started a very unique space programme in the early formative years of the nation focused on the benefits of space technology to national development. The founding visionary, Dr. Vikram Sarabhai, shaped the space programme in such a way that we are second to none in the application of space technology for the benefit of the common man in India. This application driven space programme of India is unique and highly appreciated across the world and continues to inspire other developing nations.
- The high success rate and the cost-effective nature of our Lunar and Mars missions have caught global attention. India's first lunar mission discovered water molecules on the moon in its first mission itself. The second lunar mission, Chandrayaan-2, has the highest resolution camera (28 cm) in the world that continues to map the moon.
- When Chandrayaan-3 satellite became the first satellite in the world to touch the south pole region of the Moon, it also touched the heart of every Indian and the whole world watched and hailed the achievement. It was the first time in-situ measurements of lunar elemental composition, temperature profile etc. were conducted near the south pole of the moon. India became the first country to accomplish the landing mission in the South Pole region of the Moon.
- India achieved successful insertion of Mars Orbiter Mission in its first attempt and was the first country to achieve this milestone in 2014. India's first solar mission, Aditya-L1, that was launched in 2023, making it the fourth Country to launch a solar observatory. The spacecraft continues to contribute to the global knowledge about the Sun and the science data of Aditya-L1 satellite was made available to global science community in the beginning of this year.
- The first development flight of Test Vehicle (TV-D1) was successfully accomplished with in-flight abort demonstration of Crew Escape System.
- As a precursor to the future Gaganyaan missions, India became the fourth nation in the world to accomplish autonomous docking of spacecraft in space through the SPADEX mission this year 2025. ISRO demonstrated multiple docking operations along with power transfer between the spacecraft, thereby enabling future docking missions. Recently, in July 2025, first Indian astronaut or Gaganyatri has safely return back from the International Space Station.

Accomplishments in Space – at a glance

- **133 Satellite Missions**
- **102 Launch Vehicle Missions**
- **5 Technology Demonstration Missions**
- **4014 Sounding rockets**

240 Missions



** Planned in FY2025-26*

No. of Missions doubled in the last 10 years

Current Scenario

- Government of India announced space reforms in 2020, that have resulted in far- reaching impact on the space ecosystem in the country and inspiring youth towards a career in space. About 330 space start-ups have come up in the country today from just 1 company about 10 years ago. Two of them have already conducted test launches from Indian soil and some have sent satellites to space, something which was unthinkable just 10 years ago.
- India has positioned an Indian Space Policy-2023 as an overarching, composite and dynamic framework to promote greater participation of Non-Governmental Entities (NGEs) in the value chain of space economy in order to develop robust, innovative and competitive space ecosystem aiming for a larger share of India in global space economy. Also, India has revised and liberalized FDI policy in space sector.
- India is moving towards a leadership role in the space-sector, especially in the global south. ISRO has launched the South Asia satellite to share our space platform for satellite communication with South Asian countries. ISRO also assisted Bhutan in harnessing the benefits of space technology through the Indo-Bhutan joint satellite along with skill development and ground segment.
- Launch of NASA-ISRO Synthetic Aperture Radar satellite (NISAR) in July 2025, for which half of the payload, the spacecraft itself and the launch was provided by India. India is leading the development of a G20 satellite that will also host payloads from some of the G20 nations towards environment monitoring and climate change.
- India's space programme has steadily elevated to higher technological capabilities while also touching ordinary lives across the country. The vision and foresight of the earlier generation of leaders continues to guide the national space programme towards greater heights.

Vision Statement

Development of Indian Space Ecosystem for space exploration, applications and sustained human space missions, while evolving space based critical technologies for societal applications.

Mission Statement

- To realise this vision, a series of Gaganyaan and Chandryaan follow-on missions, Venus Orbiter mission, 1st module of Bharthiya Antariksha station are envisaged including the development of heavy lift Next Generation Launch Vehicle (NGLV) and super heavy lift Moon rocket to take our Gaganyatris to the Moon and back.
- Positioning India as Global Leader in Earth Observation Science and Application for natural resources management, building resilient society and improving the quality of life.
- Enhance nation's share in global space economy need to be strengthened. The space industry in India is a crucial driver of economic growth. The space economy has grown and is essential to the country's high-tech manufacturing and services sectors. India's space sector is ready for the next leap, with ISRO securing a leading position in launching satellites. India's current contribution to global space economy is valued at around $8.4 billon is about 2-3%, with the target to progressively increase this number to $ 44 billion with 8% of global share by 2033 and $ 100 billion with 10% of global share by 2040.
- Fortify institutional capacity building and enhance outreach initiatives

Space-based benefits

India has been successfully making significant strides in the space sector. Space missions have established India's position as a major space faring nation. These initiatives have, in addition to tangible benefits of technological and scientific advancement, soft benefits such as uplifting the scientific temperament, early inculcation of scientific interest in the young population and a general feeling of pride in the country's population.

The Indian Space Programme is also constantly touching the lives of every citizen through various space-based services enabled by our multiple eyes in the sky:

- Early warning for tropical cyclones enabled through space technology have saved thousands of lives till now and eased evacuation and rescue efforts. Satellite Aided Search and Rescue (SASAR) Programme provides operational services to the users in India and seven neighbouring countries. The programme has so far supported rescue of 2446 lives in 196 incidents, as on date.
- Satellite data is used to generate advisories on potential fishing zones, reaching nearly 7 lakh fishermen and 1200 Fish Landing Centres. The benefit is 2 to 4 times increase in fish catch per effort and 30-40% reduction in search time, and resultant savings on fuel cost. Further, the Government has implemented a programme to supply 1 lakh mobile satellite service terminals across 13 coastal states to ensure the safety of fishermen at sea.
- The constant satellite data inputs from our high resolution Cartosat remote sensing satellites have helped the effective management of Kumbh Mela.

- Data from satellites are ensuring the food security of the nation by providing multiple forecasts of crop production ahead of harvesting, for 10 major crops, towards informed decisions on stock & price management and export/ import policy decisions.
- Space technology is enabled in the Pradhan Mantri Fasal Bima Yojana programme for major crops such as rice and wheat, for faster claim settlement for the farmers.
- Telemedicine through our communication satellites is benefiting the patients in the remote border areas and the islands.
- Geospatial technology is implemented in one of the largest citizen benefit programmes of the world; MGNREGA, for monitoring the progress and planning of creation of assets & activities. Nearly 6.3 Crore assets are geotagged on the Bhuvan based GeoMGNREGA portal.
- Satellite data and geospatial decision support tools are used for developing India's Water Resources Information System, benefiting comprehensive management of national water resources.

Strategic Goals and Roadmap

- The first uncrewed mission of Gaganyaan is planned this year to demonstrate the associated technologies for human spaceflight. After two more such uncrewed missions to establish reliability, Gaganyatris are expected to take off from Indian soil in two years from now.
- Demonstrate critical Technologies for enabling sustained space exploration, new space science mission with advance sensors / payloads, Docking experiments in earth and moon orbits, Extra-terrestrial copters, Landing technology in harsh environments, long duration explorations, etc.
- To finalize the configuration of the Bharatiya Antariksh Station that has 5 modules and the launch of the first module is targeted by 2028.
- As part of the expansion of ground infrastructure for achieving the Space Vision, to setup two more launch pads – one at Kulasekrapattinam in Tamil Nadu and a Third Launch Pad for the Next Generation of Launch Vehicles at SDSC, Sriharikota.
- Systems readiness for the Heavy Lift Next Generation Launch Vehicle (NGLV).
- To finalize the configuration and initiate the development of a super heavy lift Moon rocket to take our Gaganyatris to the Moon and back.
- PSLV and SSLV Production and Launch by Industry.
- Promulgate Space Activities Bill in order to provide a regulatory certainty and level- playing field for activities of NGEs.
- Share Technologies, Process and best Practices, thereby enabling permeation of know-how from ISRO to private sector.
- Enhancing the NavIC regional coverage.
- The Indian Space Programme has also set its sights high in the next 25 years by foster Space Applications towards supporting National development, building resilient society & better understanding of Earth System, involving all stakeholders.
- As part of our outreach activities, to establish Space Museums, Knowledge Centres, Planetariums, and Space Science Centres in Kanyakumari, Thiruvananthapuram and Kolkata to inspire young minds across the nation.

Conclusion

The various initiative in the space sector and the goals identified under the Space Vision 2047 will elevate the Indian Capability in launch vehicles, satellites, space science and space applications on par with the leading space faring nations by the 2040-45 timeframe and contribute to the vision of Viksit Bharat.

Note

Note

सत्यमेव जयते

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DEPARTMENT OF
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UNDER THE GUIDANCE OF

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Office of the Principal Scientific Adviser to the Government of India

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