

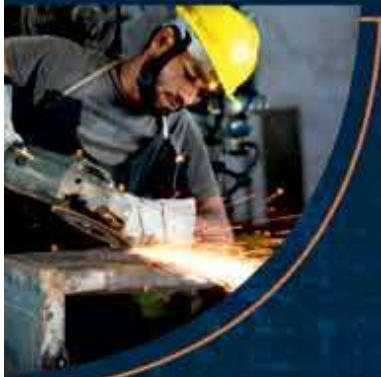


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India, with its rich heritage in science and technology, stands at a unique crossroad to blend traditional wisdom with modern advancements. From Ayurveda and ancient architecture to foundational principles of chemistry and materials science, our historical contributions offer a wealth of untapped knowledge. By harnessing modern tools such as AI and other technologies, India has the potential to create a new paradigm for global scientific progress, offering innovative solutions that combine ancient wisdom with cutting-edge science. By strategically harnessing science and technology, India aims to tackle critical national challenges, foster sustainable economic development, and secure a competitive edge on the global stage. This article explores India's strategic priorities, key focus areas, and the roadmap to leverage scientific and technological innovation for a prosperous and resilient future.

India's progress in the realm of science and technology over the past decade has been nothing short of extraordinary, driven by unwavering commitment and strategic initiatives. As the nation charts its course toward global leadership, it stands poised to leverage its technological prowess, youthful and dynamic workforce, and robust

public-private sector collaboration to catalyse transformative growth. By strategically harnessing science and technology, India aims to tackle critical national challenges, foster sustainable economic development, and secure a competitive edge on the global stage. This article explores India's strategic priorities, key focus areas, and the roadmap to leverage scientific and technological

ANRF's Partnerships for Accelerated Innovation and Research (PAIR) Program

Objective

- Transforming Research and Innovation in Indian Universities
- Fostering research excellence in universities, aligned with NEP 2020

Eligibility

Hub Institutions

- Top 25 NIRF-ranked institutions
- Institutions of National Importance within top 50 of the NIRF ranking

Spoke Institutions

- Central and State Public Universities
- Selected NITs and IITs

Start Date: 14 November 2024

Last Date: 31 December 2024



innovation for a prosperous and resilient future.

During the last few years, India has achieved several key milestones in the science, technology, and innovation landscape:

- India has significantly improved its global standing in scientific research, advancing from 7th position in 2010 to 3rd position currently. Over the past five years, India has surpassed the United Kingdom, Germany, and Japan in terms of annual scientific publications. The nation's scholarly output in Science and Engineering has surged from 78,135 publications in 2012 to 207,390 in 2022, underscoring a robust growth trajectory in academic research.
- India ranks 3rd globally in the number of PhDs awarded in Science and Engineering, following the United States and China. This reflects the country's expanding capacity for high-level research and development in scientific disciplines.
- India has made notable strides in the Global Innovation Index (GII), climbing from 81st position in 2014 to 39th in 2024. This advancement highlights our growing innovation capacity and the successful implementation of strategic policies to enhance its global competitiveness in technology and research.
- Our patent filings doubled between 2018 and 2023, and the country now ranks 6th globally

with 82,811 patent filings.

- Our start-up ecosystem has experienced remarkable expansion in recent years. The country is now the third-largest start-up hub globally, with the third-highest number of unicorns. The total number of startups has surged to 140,000 in 2024, up from just 450 in 2016, while the number of unicorns continues to stay over 115. This growth underscores India's burgeoning entrepreneurial spirit and its role as a critical player in the global innovation economy.

These advancements collectively underscore India's growing stature as a global leader in science, technology, and innovation, driven by strategic investments and an increasingly vibrant ecosystem.

While the aforementioned indicators reflect India's remarkable progress in science and technology, several critical challenges remain that require concerted attention in the years ahead. Notably, the nation's research and development (R&D) expenditure as a percentage of GDP stands at a relatively modest 0.64 per cent, which is significantly below the global average of 1.79 per cent. In comparison, leading economies such as China (2.43 per cent), the United States of America (3.46 per cent), and South Korea (4.93 per cent) spend considerably higher portions of their GDP for R&D, underscoring a gap in investment that needs attention. The number of full-time equivalent R&D professionals per million population in India is a mere 262, a figure that lags behind other major economies. This highlights the need for greater investment in human capital and capacity building within the research and innovation sectors. Low expenditure in R&D is partly due to low private sector investment in R&D, which accounts for only 37 per cent of the total expenditure. This is in stark contrast to countries such as China (77 per cent), the United States (78 per cent), and South Korea (79 per cent), where private sector contributions to R&D are significantly higher. The disparity suggests that we must incentivise private sector and create a more conducive environment for private industry to increase its involvement in innovation and technological development.

To navigate emerging global challenges and ensure sustainable growth, we need to

adopt a strategic, future-oriented roadmap with clear, measurable goals. We should prioritise solutions that address our societal needs while focusing on disruptive technologies that enhance technological sovereignty, global competitiveness and address sustainability, resilience, and resource optimisation. By strengthening these key domains, we can tackle not only the domestic challenges but also position ourselves as a leader in contributing to global solutions.

Sustainability and Fragility: Addressing the multifaceted challenges of global climate change, driven by greenhouse gas emissions and fossil fuel overconsumption, requires transformative technologies such as e-mobility, green hydrogen, nuclear energy, photovoltaics, and solar cells for decarbonising energy systems and transitioning to a low-carbon economy. We also need to build a strong capability in supply-chain in these sectors for strategic autonomy. Simultaneously, to counter emerging geopolitical threats, including cyber warfare and the proliferation of advanced weaponry, developing capabilities in Artificial Intelligence (AI), cybersecurity, and quantum cryptography is essential. These innovations are critical to enhancing national security, achieving strategic autonomy & resilience, while safeguarding

infrastructure in an era of evolving technological warfare.

Resource Constraints: The inexorable pressures of a burgeoning global population, rapid urbanisation, and shifting consumption patterns are precipitating acute strains on critical resources, notably in the realms of food and water. To mitigate these challenges and ensure long-term resource sustainability, it is essential to focus on the advancement of technologies such as precision agriculture and the development of advanced materials. Moreover, the global demand for critical minerals—such as lithium, nickel, cobalt, graphite, and rare earth elements—has escalated, driven by the rapid expansion of clean energy technologies and the proliferation of industries such as electronics, telecommunications, transportation, and defense sectors. To address vulnerabilities in the supply chains for these essential minerals, the deployment of cutting-edge technologies in advanced manufacturing, AI-driven optimisation, quantum sensors, deep-sea mining, and deep space exploration will be indispensable. These technologies will not only enhance the efficiency of resource extraction but will also contribute to the resilience and diversification of the critical minerals value chain.

Longevity and Viability of Life: With the steady increase in India's elderly population, advances in healthcare and medical technologies, including assistive technologies, will be paramount in addressing healthcare challenges associated with an aging society. While we focus on modernising healthcare system, need for preventive healthcare is also extremely important for a healthy lifestyle. Simultaneously, rapid urbanisation demands sustainable solutions in transportation, housing, infrastructure, and pollution control. Technologies optimising transportation, housing, infrastructure, and pollution control, while enhancing digital connectivity, are key to building sustainable, livable cities.

The aforementioned technologies must be pursued with resolute commitment, as they hold transformative potential to tackle critical societal challenges and enable sustainable futures. Their deployment is not merely an opportunity but an urgent imperative to counter the multidimensional risks of climate change, resource depletion,





and geopolitical volatility. By strategically advancing these technologies and ensuring robust investment, India can forge a resilient, inclusive, and sustainable society, positioning itself as a global frontrunner in innovation-driven solutions to address the existential threats of the future. While our strategy should harness near-term opportunities in sectors like AI, telecom, semiconductors and space by leveraging existing expertise and policies, long-term investments are needed in disruptive technologies such as quantum computing, biomanufacturing, advanced materials, and green tech, requiring substantial R&D and capital. We need to focus on long-term funding, private sector collaboration, and innovation hubs to integrate R&D with industrial-scale application.

The Australian Strategic Policy Institute's *Two-Decade Technology Tracker: The Rewards of Long-Term Research Investment* report (August 2024) elucidates India's ascension as a burgeoning nexus of scientific and technological primacy, positioning itself as an emergent global S&T superpower. The report reveals India's prominence within the top quintile of nations across 45 of the 64 critical technologies, encompassing domains such as defence, space, energy, artificial intelligence, biotechnology, and advanced materials. Noteworthy sectors in which India has entrenched its leadership include smart materials, biofuels, natural language processing (NLP), AI algorithms, photovoltaics, cybersecurity, quantum sensing, quantum cryptography, advanced optical

communications, photonics, drones, and robotics.

While the above accomplishments demonstrate an impressive research portfolio, the imperative now lies in translating this intellectual capital into scalable, high-impact technological infrastructure. To this end, our government under the visionary leadership of Prime Minister Narendra Modi has instituted a series of high-stakes mission-driven initiatives, including the National Quantum Mission, the National Mission on Interdisciplinary Cyber-Physical Systems, the IndiaAI Mission, the India Semiconductor Mission, the National Green Hydrogen Mission, and Mission Mausam, among others.

BioE3 (Biotechnology for Economy, Environment and Employment) Policy, recently approved by the government for fostering biomanufacturing, is set to drive India's bioeconomy to US\$ 300 million by 2030 and accelerate green growth. We are poised to become a global leader in bio-economy with a vibrant ecosystem for bio-based chemicals, precision biotherapeutics and lab-grown foods.

Fuelled by technological prowess, indigenous capabilities and continued success, India is set to take a giant leap in global space race through several ambitious space mission programs such as *Chandrayaan 4*, India's next leap towards lunar exploration, commissioning of the *Bharatiya Antariksha Station*, India's first space station module by 2035, *Gaganyaan Mission*, launching a three-member crew into space, and India's astronaut landing on the moon by 2040. We would be a vibrant space manufacturing hub with enhanced private sector participation and a 15 per cent share of the global space economy.

These mission-mode programs, engineered with targeted interdisciplinary focus, are designed to catalyse India's trajectory toward technological ascendancy, with additional mission-mode frameworks under consideration to expedite the nation's S&T (Science and Technology) prowess and consolidate its strategic competitive advantage on the global stage.

India, with its rich heritage in science and technology, stands at a unique crossroad to blend traditional wisdom with modern advancements. From Ayurveda and ancient architecture to foundational principles of chemistry and materials science, our historical contributions offer a wealth

of untapped knowledge. Strengthening these traditional sciences and integrating them with modern research methodologies has the potential for ground-breaking discoveries. By harnessing modern tools such as AI and other technologies, India has the potential to create a new paradigm for global scientific progress, offering innovative solutions that combine ancient wisdom with cutting-edge science.

We are strengthening our technological leadership with the establishment of the Anusandhan National Research Foundation (ANRF) under the ANRF Act 2023, marking a paradigm shift in our R&D ecosystem. The ANRF will drive a multi-phased roadmap for scientific breakthroughs and cross-sectoral collaboration, providing competitive, peer-reviewed grants to optimise resource allocation for high-impact research. Serving as a central nexus for coordinating efforts across government, industry, and academia, the Foundation will track scientific outcomes while enhancing India's participation in global research consortiums. ANRF aims to position India as a global leader in innovative, sustainable technological progress. The Foundation has outlined multifaceted strategic interventions to enhance India's research ecosystem, aligning with national scientific and geopolitical priorities. These include:

(i) **Global Positioning:** Aligning R&D with national imperatives to advance scientific frontiers while strengthening India's global geopolitical influence;

(ii) **Promoting Inclusive Growth:** Building R&D capacities in our central and state universities where research is still at nascent stage, ensuring equitable access to advanced scientific resources and fostering decentralised innovation;

(iii) **Excellence in Science:** Cultivating high-impact research ecosystems that drive cutting-edge, frontier technologies and position India as a global leader in innovation;

(iv) **Capacity Building:** Developing world-class infrastructure and a skilled, multidisciplinary workforce to support sustainable, long-term growth across strategic sectors; and

(v) **Industry-Aligned Translational Research:** Bridging the gap between academic research and industrial applications through robust translational efforts, accelerating commercialisation and fostering knowledge-driven entrepreneurship. These pillars aim to institutionalise an integrated, coordinated, and forward-looking research landscape, positioning India as a leader in both technological innovation and economic growth.

While we have emerged as the third largest startup ecosystem in the world, we have the potential to become global startup capital in deep tech. The government has already announced an ambitious plan to establish a Rs 1 lakh crore R&D fund to encourage the private sector to scale up research and innovation in sunrise domains. It is expected to create industries of global eminence to drive '*atmanirbharata*' in technology.

In conclusion, our aspiration to establish ourselves as a global leader in science and technology is primed for fruition through a series of strategically orchestrated investments, synergistic collaborations, and the institutionalisation of a robust, globally competitive research ecosystem. By nurturing intellectual capital, strengthening public-private alliances, and prioritising disruptive technologies, Bharat is charting a definitive course towards becoming a product nation and achieving strategic autonomy while simultaneously catalysing socioeconomic development of the country. This forward-thinking approach will not only bolster *Bharat's* geopolitical standing but also ensure the enduring sustainability and resilience of its scientific and technological infrastructure, leading to realising the vision of *Viksit Bharat* by 2047. □

