

Policy Brief No. 229 – March 2026

Technology Policy and Diplomacy: The Indian Experience

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Key Points

- Science and technology (S&T) is a key vector for economic growth and national power.
- India has developed a dynamic technology policy aligned with development priorities, pursued indigenous advancement and built centres of excellence.
- S&T education has trained a large pool of researchers and engineers but few institutes have attained global standards. Higher resource allocation is necessary for S&T research, innovation and diplomacy.
- India's technology diplomacy focuses on collaborations in key sectors for sustainable development to stay ahead in future-oriented domains.
- Technology diplomacy has been successful in strategic areas and development priorities, including creating research ties with certain countries, attracting scientific talent in the Indian diaspora and encouraging private endowments.

Introduction

India has a significant footprint in the technology landscape with global leadership in niche areas and it regards technology as a key vector for economic growth and national power (Balakrishnan 2017). Its S&T policy framework has highlighted education, research and development (R&D) and innovation while pursuing self-reliance. This has facilitated rapid growth, inclusive development and building capability in strategic areas. It has also empowered citizens and encouraged a dynamic scientific temperament. The integration of S&T policy in development priorities optimized resource allocation, enhanced capabilities and advanced governance precedence. Technology diplomacy accessed advances developed overseas and established innovation bridges for transition to markets as well as cooperation in multilateral fora.

About the Author

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Background

In ancient India, seminal contributions in astronomy, mathematics, medicine, metallurgy and philosophy led to the development of a scientific temperament for advances in agriculture, architecture, governance and handicrafts (Basham 1954). This made India a prosperous country but much of this progress was lost during the colonial period.

In modern times, India's S&T policy has evolved over three phases: the post-independence framing of S&T priorities and policy, establishing infrastructure for education, research and innovation, and focusing on development and select strategic areas; the post-economic reform's emphasis on technology for growth, integration in global supply chains and improved governance; and the post-digital era's adjustments for globalization, with its emphasis on the knowledge economy and the importance of critical materials and technologies, framing new rules as well as the role of technology diplomacy.

S&T Policy Approach

India leveraged S&T to promote growth, lift millions out of poverty, rejuvenate its scientific temperament and build world-class institutions. Recognizing its importance, India's first prime minister, Jawaharlal Nehru, directly oversaw key scientific departments (a tradition that continues). He invited foreign scientific advisers to build key infrastructure projects, what he called the "temples of modern India." This quest for a modern approach coexisted with Gandhian ideals of village-level enterprises; a popular movement for customary agrarian practices and small projects; and Western ideals of appropriate technology and South-South cooperation (Chaturvedi, Srinivas and Rastogi 2015).

These diverse strands led to an inclusive approach to India's S&T policy framework.

The milestones that trace its development are reflected in the following documents:

- the Scientific Policy Resolution, which reflected on the potential of S&T for economic growth and creating a dynamic, knowledge-based society (Government of India 1958);
- the Technology Policy Statement, which focused on self-reliance, the promotion of indigenous technology and the absorption of foreign technology (Government of India 1983);
- the Science and Technology Policy, which mentioned the role of international cooperation and diplomacy (Government of India 2003);
- the *Report of the High-Level Committee on Developing Science & Technology Clusters*, which discussed linking education, research, industries and start-ups (Government of India 2020);
- the *Report on International S&T Cooperation*, which emphasized self-reliance, the diversification of partnerships and a citizen-centric approach (Department of Science and Technology [DST] 2021);
- the India Semiconductor Mission, which began in 2021, urged the development of a complete ecosystem for design, manufacture and assembly;¹ and
- the Engagement Strategy for Quantum (PIB Delhi 2025b) and the Nuclear Energy Mission (PIB Delhi 2025a), among others, which include other recent key documents.

The policy-making structure is led by the principal scientific adviser to the government of India (PSA), who coordinates the ministries and specialized agencies. A defined S&T policy framework and its periodic review have provided a dynamic environment. Special reports on new and emerging areas have been commissioned by the PSA, often involving foreign experts. S&T policy has provided the basis for resource allocation and diplomatic outreach. From the outset, this policy has emphasized the development of indigenous capacity, self-reliance and innovation, alongside external engagement and multilateral cooperation (Kumar 2016).

1 See <https://ism.gov.in/>.

The institutional framework for research is led by the Council for Scientific and Industrial Research (CSIR) (Ghoshal, Piramal and Budhiraja 2001), which promotes research and coordinates with foreign partners. The CSIR *Vision & Strategy* Document outlined goals for national S&T missions, establishing a global R&D platform and incentives for patents and innovation, while the more recent CSIR *Vision 2030* report provided for perspective planning in frontier areas (CSIR 1996, 2023). A network of laboratories under the guidance of the DST and the Department of Atomic Energy (DAE) — as well as the departments of space, defence, agriculture, health and so on — formed the backbone of state-sponsored efforts, particularly during the five-year plans. Notable world-class scientific research institutions initiated by the private sector include the Indian Institute of Science, the Tata Institute of Fundamental Research and the Atomic Energy Establishment in Trombay, later renamed the Bhabha Atomic Research Centre (BARC).

India's external S&T engagement is led by the PSA and coordinated by the Ministry of External Affairs (MEA) and the DST, the latter of which has 83 bilateral cooperation agreements for research and exchanges. India also partners with international institutions to fund projects and access-inclusion-equity initiatives, as well as share outcomes. The DST has adopted multidimensional metrics, including capability development, economic impact and value alignment. This evaluation of technology preparedness has helped India to access international funding mechanisms.

Post-Independence Development Priorities

After gaining independence, India's initial focus was on improving livelihood conditions. The Indian Council of Agricultural Research launched the Green Revolution in the 1960s, in collaboration with US scientists and the International Agriculture Research Institute, to introduce high-yield hybrid crops, changing India's agriculture profile from that of a grain shortage to self-sufficiency. A similar White Revolution, which made India the leading global milk producer, benefited from a home-grown cooperative dairy movement, indigenous

technologies and European funding. Meanwhile, the CSIR focused on improving the scope and scale of industrial activity and the Indian Council of Medical Research led research on tropical diseases and vaccines. India established partnerships with international scientific institutions and also shared its achievements through South-South cooperation.

The development of human capital was another priority following independence. The Indian Institutes of Technology were established in collaboration with top technology institutes from Germany, Japan, Russia, the United Kingdom and the United States, while industrial training institutes for skills development were launched with overseas partners. In addition, India established medical research partnerships with Western institutes, multilateral agencies and pharmaceutical companies.

Focus on Strategic Sectors

Post-independence, India prioritized the development of indigenous capabilities in strategic areas that were supported by cooperation with international research projects and bilateral partners. Over the decades that followed, India achieved technology dominance that enhanced its power and status, confirming its capability in frugal R&D and global leadership in niche areas.

In space, the Indian Space Research Organisation (ISRO) pursued development priorities as well as space exploration. ISRO's success in launch capability and building a satellite network for communication, imaging, metrology and resource mapping helped advance the fields of agriculture, education, health and navigation. Its space milestones included the Chandrayaan mission's soft landing on the Moon and subsequent discovery of water there, the Mangalyaan interplanetary Mars orbiter mission, and the Aditya solar mission, as well as the upcoming mission to Venus and manned spaceflights. ISRO projects were implemented with very tight budgets and high indigenous content but also close foreign cooperation. ISRO has cooperation agreements with 61 countries and five multilateral institutions, including Roscosmos in Russia; the National Aeronautics and Space Administration in the United States; the European Space Agency; the Japan Aerospace Exploration Agency; and the Centre national

d'études spatiales in France, as well as commercial ventures with SpaceX and others to enhance technology, capability and efficiency. In addition, ISRO has extended its support to several developing countries to help improve their space capabilities.

In atomic energy, India had an early start with scientists, fundamental research institutions and energy producers all contributing to this field. External collaboration following the nuclear tests in 1974 was largely confined to Russia and France for technology and a few other partners for raw materials. Following the civil nuclear agreement with the United States and domestic civil liability legislation, the potential for more partners grew. The Nuclear Power Corporation of India, which currently operates eight nuclear power plants, is developing additional facilities with foreign partners to generate a 100-gigawatt capacity by 2047. This recent Nuclear Energy Mission seeks public-private partnerships (PPPs) to enhance nuclear energy capacity by setting up small modular reactors (SMRs), large nuclear plants and advanced technologies. BARC's recent prototype for SMRs could be a game changer with significant export potential. India is a key partner at the European Organization for Nuclear Research and the International Thermonuclear Experimental Reactor. The DAE has civil nuclear cooperation agreements with a dozen countries in agriculture, energy generation, health, regulatory, safety, technology and other areas.

In defence, India's focus on indigenous technology and capacity building coexists with technology collaborations, co-development and joint production with partner countries. The Defence Research and Development Organisation (DRDO) leads the technology upgrading process, holding several partnerships with private-sector and foreign entities. Following recent reforms and public-sector undertakings, the private sector is now also engaged in defence. India has cooperated with key partners to develop an ecosystem for start-ups and new innovations in drones, electronic defence systems, lasers, missiles and other technologies.

New Orientation Post-Economic Reforms

Following a period of economic reform and liberalization in 1991, India integrated technology policy into its development strategy. The technology vector was used to promote reforms for the adoption of global best practices, industry-led R&D, innovation support for transfer to markets, intellectual property (IP), inventors' incentives and patents. Private-sector participation expanded the scope of technology collaborations.

Next-generation agriculture reforms to enhance farmer income involved technology collaborations to introduce cold chains, innovations in agro-industry, a market-oriented approach and product diversification. In health care, faced with high-cost imported pharmaceutical products, Indian laboratories achieved breakthroughs in inexpensive generic formulations, medicines for tropical diseases, pharmacopeia for traditional remedies, a reliable and low-cost health stack for improved health security and scale production of vaccines. India's role in providing vaccines and health services to 98 countries during the COVID-19 pandemic, including the COVID Vaccine Intelligence Network vaccine management application, was an example of the country's diplomacy.

While traditional sectors have continued to be prioritized, new issues related to climate change, green energy, information technology, materials science, semiconductors and other areas have also grown increasingly important.

Post-Reforms Push in Industrial Technology

India's public sector, which dominated its basic industries and capital-intensive fields, has relied on government-to-government collaborations for licensed production, R&D cooperation with foreign partners and technology transfers. Over time, the private sector has grown, building supply chains for technology, as well as resource and capital flows, to meet the demands of the country's growing middle class.

After economic reforms and liberalization in 1991, India's economy grew rapidly across sectors. India contributed to global manufacturing and supply and value chains, while globalization provided new collaborations in investment and technology. India built a robust legislative framework for the protection of IP to address the concerns of developed countries. Many Indian public- and private-sector companies established joint ventures with foreign partners, commercial presence in global markets, and technology transfers and joint R&D.

In 2014, the Indian government launched the Make in India initiative² to strengthen the manufacturing sector and promote small- and medium-scale enterprises. It enhanced domestic production and export capacity while supporting foreign collaborations in logistics, manufacturing and services. The government also launched the Production Linked Incentive (PLI)³ Scheme to attract foreign companies to develop scale economies and supply chains for the large domestic market and export potential. These collaborations boosted India's manufacturing sector to increase output share and integration in global markets.

New Critical Materials and Technologies in a Digital Era

In India, new digital technology permeates all spheres of activity. Digital development depends on critical materials and technologies. India seeks

- ² The Make in India initiative covers 27 sectors, with a focus on aerospace and defence, automotive and auto components, biotechnology, capital goods, chemicals and petrochemicals, electronic systems design and manufacturing, food processing, gems and jewellery, pharmaceuticals and medical devices, renewable energy, and textiles and apparel. In addition, it provides incentives to the services sector, including information technology (IT) and information technology-enabled services, medical travel, tourism and hospitality, and transport and logistics. See [www.dpiit.gov.in/ministry/about-us/details/Title=Make-in-India-\(MII\)-ITMwETMtQWa](http://www.dpiit.gov.in/ministry/about-us/details/Title=Make-in-India-(MII)-ITMwETMtQWa).
- ³ The PLI scheme covers 14 sectors: advanced chemistry cell batteries, automobiles and auto components, bulk drugs, drones and their components, food processing, high-efficiency solar photovoltaic modules, IT hardware, large-scale electronics manufacturing, medical devices, pharmaceuticals, specialty steel, textiles, telecom and networking products, and white goods. See www.meity.gov.in/offerings/schemes-and-services/details/production-linked-incentive-scheme-pli-for-large-scale-electronics-manufacturing-gNyMDOtQWa.

to plug into reliable and resilient value and supply chains that are essential in a globalized world.

The country's policy on priority materials and critical technologies is dynamic. India keeps track of technology trends and the experiences of other countries. The initial critical materials list⁴ included 30 items deemed essential for economic development and national security. It considered minerals and rare earth elements for their economic importance and supply risk using parameters such as cost-cutting usage across sectors, disruption potential, import reliance, recycling fees, sustainability and so on. To avoid disruptions, the government developed a reserve-stock policy based on resilient supply arrangements from reliable partners. A centre of excellence for critical minerals was created to establish an effective value chain for these materials in the country and for external collaborations. The critical minerals supply chain ecosystem was based on upstream exploration, mining and extraction; midstream processing, refining and metallurgy; downstream component manufacturing and clean digital and advanced technology production; and material recovery and recycling.

India does not have a formal list of new and emerging technologies that it prioritizes but a range of technologies is assuming importance, especially those linked to data and information systems, energy and national security. An examination of the experience of other countries, including

the United States⁵ and Australia,⁶ revealed that critical technologies may be diverse and dynamic. However, as in the case of critical minerals, there is a need for strong and enduring collaborations with key partners to establish reliable and resilient linkages in R&D and its outcomes. These future collaborations have emerged as priorities in India's technology diplomacy, both bilaterally as well as in certain groups such as BRICS⁷ and the Quad⁸ (Quadrilateral Security Dialogue).

The Knowledge Economy and Future Direction

In the era of disruptive technology, knowledge-intensive products and services have an edge in economic growth, with higher profitability, market penetration and social impact parameters. India's policy to transition to a knowledge economy seeks inputs in all sectors for improved efficiency and productivity. The use of data-based IT systems in agriculture, AI and quantum computing in emerging industries, and evidence-based policy making in development plans and the health and service sectors is growing in India. As new investments seek markets with greater potential, India has positioned itself as a hub of value and supply chains that

4 The critical materials list includes: antimony, beryllium, bismuth, cadmium, cobalt, copper, gallium, germanium, graphite, hafnium, indium, lithium, molybdenum, nickel, niobium, phosphorus, platinum-group elements, potash, rare earth elements, rhenium, selenium, silicon, strontium, tantalum, tellurium, tin, titanium, tungsten, vanadium and zirconium (Ministry of Mines 2023).

5 The US critical and emerging technologies list includes: advanced and networked sensing and signature management; advanced computing; advanced engineering materials; advanced gas turbine engine technologies; advanced manufacturing; AI; biotechnologies; data privacy; data security and cybersecurity technologies; directed energy; green energy generation and storage; highly automated, autonomous, unscrewed systems and robotics; human machine interfaces; hypersonics; integrated communication and networking technologies; positioning navigation and timing technologies; quantum information and enabling technologies; semiconductors and microelectronics; and space technologies and systems (Fast Track Action Subcommittee on Critical and Emerging Technologies 2024).

6 The Australian list of critical technologies in the national interest includes: advanced information and communication technologies; AI technologies; autonomous systems, robotics, positioning, timing and sensing; biotechnologies, clean energy generation and storage technologies; and quantum technologies (Department of Industry, Science and Resources 2023).

7 BRICS is an intergovernmental organization made up of the following countries: Brazil, Russia, India, China, South Africa, Egypt, Ethiopia, Indonesia, Iran, Saudi Arabia and the United Arab Emirates (UAE), and several partner countries.

8 The Quad is an intergovernmental security forum made up of Australia, India, Japan and the United States.

drive future growth, offering ease of doing business, higher returns and IP protection.

In the India Semiconductor Mission, the Indian government led from the front to develop a favourable regulatory regime for technology collaborations with R&D leaders and manufacturers, engaging directly with foreign partners and supporting domestic entrepreneurs in investments or joint ventures. When India unrolled its 5G network, the country chose Finland as a partner, based on security considerations and also for assistance in retrofitting existing 4G networks. Similarly, collaborations in other strategic areas, such as AI, green energy and so on, were also supported. These collaborations often yield spin-off benefits in development areas.

With economic development, there has been an expansion of R&D activities but R&D investment has remained limited and below the levels in developed countries (Government of India 2024). Although the R&D sector has registered growth with the doubling of expenditure over the previous decade, a four-fold increase in patents issued in the past five years and an improvement in the Global Innovation Index, the overall share of R&D investment to GDP remained low at 0.64 percent in 2024 (compared to 2.4 percent in China and 3.5 percent in the United States) (ibid.). While state-sponsored R&D was the mainstay, the private sector contributed just 36 percent (compared to 77 percent in China and 75 percent in the United States). Private-sector R&D in agriculture, chemicals, manufacturing and pharmaceuticals has the potential for growth. Further, the link between higher education, industry and research needs to be strengthened and “lab-to-land” time needs to be reduced such that technologies developed in institutions can be transformed to more efficiently provide societal benefit.

The growth of start-ups, especially in tier II and tier III cities, and the success of several unicorns have been positive developments. The start-up ecosystem has matured with a vibrant research environment in technology and business schools; a supportive financial network of angels, venture capitalists and private investors; and a bullish capital market in support of initial public offerings. The recognition of Indian start-ups in foreign markets was encouraging and facilitated scaling up domestic operations and transboundary transactions. The diplomatic efforts to introduce Indian start-ups at the World Economic Forum in

Davos and build technology hubs and innovation bridges with foreign partners is yielding results.

The development of the India Stack began with the introduction of the unique identity Aadhar for all residents and the expansion of over 550 million new bank accounts, a scheme called “Jan Dhan.” It was not only a technological achievement for a country of 1.4 billion people, but also an expression of citizen empowerment and digital governance. The Unified Payments Interface (UPI) opened up the potential for seamless, efficient and transparent financial transactions and has grown to over 500 million transactions daily since 2024. The India Stack and the broader digital physical infrastructure (DPI) are not only massive in scale and used extensively by citizens in multiple applications but were also indigenously developed on an open-source platform. Seven countries have already adopted UPI⁹ and India has offered technical assistance to help bring DPI to many developing countries.

Technology Diplomacy and Cooperation Mechanisms

Technology diplomacy has expanded with globalization, new mechanisms and a wider range of stakeholders. India engages actively in the triad of technology-digital-cyber diplomacy, in bilateral and multilateral contexts and as both a provider and recipient of technology products.

Engaging governments, producers, scientific establishments, and public- and private-sector companies in R&D and manufacturing is a priority to access critical technologies and materials and to minimize impediments to technology transfers, such as tariffs, technology-denial regimes or trade restrictions. The Indian government coordinated the identification of priority technologies and key partners in each area central to its development strategy and facilitated tie-ups. On cyber diplomacy, India prioritized data sovereignty and security, shaping cyber norms and cooperation toward a

⁹ UPI countries are Bhutan, France, Mauritius, Nepal, Sri Lanka and the UAE.

rules-based order. The Indian Computer Emergency Response Team and the Indian Cybercrime Coordination Centre are at the forefront of domestic priorities and MEA leads in foreign cooperation. India is actively engaged in the UN Global Digital Compact as well as in initiatives at the Association of Southeast Asian Nations Regional Forum, the Group of Twenty and the Shanghai Cooperation Organisation. In addition, India provides capacity-building support in Africa and Southeast Asia.

India's technology diplomacy follows a whole-of-government approach, with the PSA in the lead, involving the departments of S&T and education, the ministries of external affairs and defence, the NITI Aayog government think tank, and other stakeholders engaged in the effort. Each stakeholder also has international cooperation units to engage with foreign countries. MEA (2024) has set up a New Emerging and Strategic Technologies division to monitor S&T developments and coordinate outreach.

New initiatives at regional or minilateral groupings supplement bilateral efforts. BRICS has been at the forefront of S&T collaboration with its establishment of the BRICS Innovation Network, Young Scientists Conclave and cooperation in areas such as advanced materials, AI, biotechnology and so on. Similarly, the Quad has forged S&T collaboration in critical technologies, cybersecurity, digital infrastructure, pandemic preparedness, supporting next-generation technology leaders and so on.

Negotiations and Rulemaking

The need for multilateral negotiations for rulemaking has grown, particularly for new and emerging technologies and also for managing the changing circumstances of economic and scientific interaction. Technically competent S&T specialists work with legal experts and diplomats to conduct tough technical negotiations in multilateral bodies such as the Conference of the Parties to the UN Framework Convention on Climate Change, the International Monetary Fund, the International Organization for Migration, the United Nations, the World Bank, the World Intellectual Property Organization, the World Trade Organization and

others. In addition, most bilateral and regional trade and economic partnership agreements have a technology component and negotiations are necessary to balance national priorities with global trends. Multilateral negotiations on data and cyber issues, space applications, the blue economy and climate change have reached a critical point that requires more attention and effort. A coordinated whole-of-government approach that matches resource allocations to development priorities is essential for this urgent task.

Diaspora Initiatives

The Indian diaspora's success in scientific endeavours and laurels, including Nobel Prizes, represents the depth of its excellence. India has reached out to its diaspora to take part in national efforts to develop indigenous capacity and add value to global supply chains. Specific initiatives to engage the scientific community in the Indian diaspora, coordinated by DST (2024), DRDO and MEA, include:

- the Vaibhav Fellowship for collaboration between diaspora scientists and Indian institutions of higher learning;
- the Visiting Advanced Joint Research Faculty Scheme for innovation projects;
- the Ramalingaswami Re-entry Fellowship for scientists in biotechnology and life sciences who wish to return to India;
- the Global Initiative of Academic Networks for short-term courses and seminars at Indian universities;
- the national post-doctoral fellowships for cutting-edge research in India;
- the start-up initiative to mentor entrepreneurs; and
- the Innovation in Science Pursuit for Inspired Research program to support leadership roles in S&T.

Recommendations

- Establish a task force in MEA, working closely with the PSA to coordinate India's strategy for new and emerging technologies.
- Establish a centre for new technology to monitor developments and adapt them for use in India, focusing on AI, green energy, quantum, robotics and other strategic areas.
- Increase the budget allocation for S&T research to two percent of India's GDP and incentivize private-sector participation.
- Strengthen CSIR collaboration with private-sector research and link academic institutions and industries.
- Establish PPPs for agriculture research, digital governance, health-care management and S&T education.
- Appoint technology ambassadors to develop the capacity for negotiations on emerging issues such as climate change, data and technology, development finance, and energy transition.

Conclusion

India is a significant technology power with contributions in development and fundamental sciences that leverage future growth and national power. Technology cooperation, which initially grew with globalization, has become more challenging as nations and corporations seek to retain control with protectionist tendencies amid geoeconomic flux. This makes the task of technology diplomacy both challenging and exciting. India's approach has served the country well. It highlights an evidence-based and dynamic approach toward S&T policy; prioritizes sustainable development, citizen empowerment and national security; and promotes indigenous capacity, networks of collaboration, diversified partnerships, and reliable and resilient value and supply chains. The new challenges of a globalized world call for closer cooperation between parties that keep citizen interest and governance at the core.

Acronyms and Abbreviations

AI	artificial intelligence
BARC	Bhabha Atomic Research Centre
CSIR	Council of Scientific & Industrial Research
DAE	Department of Atomic Energy
DPI	digital physical infrastructure
DRDO	Defence Research and Development Organisation
DST	Department of Science and Technology
IP	intellectual property
ISRO	Indian Space Research Organisation
IT	information technology
MEA	Ministry of External Affairs
PLI	Production Linked Incentive Scheme
PPPs	public-private partnerships
PSA	principal scientific adviser to the government of India
Quad	Quadrilateral Security Dialogue
R&D	research and development
S&T	science and technology
SMRs	small modular reactors
UAE	United Arab Emirates
UPI	Unified Payments Interface

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