FICCI-EY report on innovation and critical technologies

September 2025

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Foreword

FICCI

India is currently at a pivotal moment where innovation and critical technologies emerge not merely as facilitators of progress, but as fundamental catalysts for transformation. The convergence of digitalization, sustainability objectives, and evolving global value chains has presented our nation with remarkable opportunities. With its extensive scale, advanced digital infrastructure, and a thriving community of entrepreneurs and researchers, India is well-equipped to not only engage in this transformative journey but also to play a significant role in shaping its trajectory.

The FICCI-EY report on innovation and critical technologies captures the evolving contours of India's technology landscape and its potential to unlock a new era of inclusive and sustainable growth. The report underscores that advancements across diverse domains—clean energy, healthcare, agriculture, biotechnology, and semiconductors—are deeply interconnected, together forming the bedrock of India's competitiveness and resilience. The report highlights the need for India to pursue ambitious, mission-driven breakthroughs that connect science, industry, and society over the next decade. As we look towards the future, India aspires to emerge as a trusted global hub for innovation, setting exemplary benchmarks in resilience, sustainability, and technological leadership.

I am confident that this report will be useful for thought leaders, policymakers, industry captains, and academia to drive this agenda forward. We appreciate the valuable contributions from all involved and hope that the insights in this report will inspire collective action. We encourage readers to embrace this opportunity and lead the world towards a future characterized by innovation, inclusivity, and impact.

Jyoti Vij
Director General, FICCI

EY

Innovation has become central to the competitive advantage of nations, companies and now, for the empowerment of citizens across the globe. Leading economies have demonstrated that innovation truly works when governments, academia, industry and startups come together to collaborate.

In the past decade, India has made tremendous progress in terms of enabling innovation. It has moved from 81st position in 2015 to 39th position in 2024 in the Global Innovation Index published by the World Intellectual Property Organization that reflects improvement in human capital, knowledge creation and market sophistication indices. This is based on the consecrated efforts put in by different government ministries and their corresponding missions.

An important element that has improved the 'ease of doing innovation' is the conceptualization, implementation and the institutionalization of Digital Public Infrastructure like Aadhaar, UPI, DigiLocker, Account Aggregator and ONDC. This has not only brought down the cost of transactions and verification of credentials but has also laid the foundational layers on which innovation and market forces can thrive.

Yet, challenges remain. India's gross R&D expenditure is around 0.66% of GDP , compared to 2%–3% in many advanced economies and more than 5% in Israel, with limited private-sector contribution.

More emphasis is needed on streamlining and replicability of intellectual property, technology transfer and commercialization of academic research. Deep-tech ventures face capital and scale barriers, and regulatory processes in sectors such as health, energy and agriculture are often protracted. In addition, talent and skill development, especially in applied sciences and design engineering, product development requires sustained investment and a conducive market environment to meet the demands of scaling emerging technology in industries and society.

The way forward is coordinated collaboration and inclusive innovation through the democratization of access and opportunities beyond existing clusters. The linkages between government, industry, academia and startups should go beyond national borders and should look at regional and purpose driven cohorts.

India now possesses the key ingredients required for a successful innovation ecosystem: a vibrant entrepreneurial base, globally respected academic institutions, committed industry players, skilled and talented workforce and an increasingly mission-driven government. The task ahead is to align these actors, so that innovation in India moves from incremental to transformational—delivering solutions that address citizen and societal challenges.

FICCI LEADS provides a platform for futurists, policy makers and representatives from the innovation ecosystem to come together and shape the path for the inclusive innovation in a world that is being reshaped by technology breakthroughs and geopolitical realignments.

This report on collaboration for innovation is therefore both timely and significant. It calls for collective action and highlights that impactful innovation can only be achieved when the key stakeholders of innovation – government, academia, industry and start-ups across borders - come together as a well networked ecosystem.

Hope you find the report useful.

Sivakumar Moorty
Partner, Technology Consulting, EY India

Introduction

Technology and innovation:
Catalyzing India's development

The Indian economy stands at a critical juncture. It is already the fourth largest economy in the world and will become, at its current growth rate, the third largest by 2030, behind just the US and China. The Indian economy's growth is being driven by dynamic policies, innovative startups, and its demographic dividend.

However, there are also some challenges on the horizon. Global warming poses a threat to our agricultural productivity. The energy demand of AI and 1.4 billion-plus people means we need to ramp up our power production, and largely through renewable energy sources so that carbon emissions are under control. Finally, the demands of the rising population have put extra pressure on our healthcare systems.

Technological advancement and innovation hold the key to addressing these challenges. They can offer solutions for sustainable growth, enhance productivity, improve quality of life, and drive economic prosperity.

The importance of technological advancement, especially Generative AI, for productivity cannot be overstated. GenAI solutions are already being adopted at scale by both the private sector as well as policy makers. Startups too have proliferated offering new solutions built on technological advances, not just in AI but also in areas such as robotics, drones, mixed reality and renewable energy, data analytics and others. Innovation, built on technological advances, acts as a force multiplier, enabling more efficient resource utilization, reducing operational costs, and creating new value propositions across industries. In a developing economy like India, where resource constraints often limit traditional approaches, technology and innovation provides pathways to leapfrog conventional development stages and achieve rapid progress.

Three sectors stand out as particularly critical for India's future prosperity: agriculture, energy, and healthcare. Agriculture, which employs nearly half of India's workforce, faces challenges of declining productivity, climate change impacts, and fragmented supply chains. The energy sector grapples with growing demand, sustainability concerns, and the need for reliable access across urban and rural areas. Healthcare confronts issues of accessibility, affordability, and quality, particularly in underserved regions.

This report examines how strategic deployment of technology and fostering of innovation ecosystems can revolutionize these fundamental sectors. Through comprehensive analysis of current challenges, emerging technological solutions, and implementation frameworks, we explore how India can leverage its digital capabilities, human capital, and entrepreneurial spirit to achieve sustainable development goals while maintaining competitive advantage in the global economy.

India's agriculture sector:

Growing with innovation

01

CHAPTER 01

Agriculture is a vital pillar of India's economy, underpinning its overall stability and growth. The sector supports around 42.3% of the country's population and contributes 18.2% to its GDP at current prices. With an average annual growth rate of 4.18% over the past five years, the sector has shown great resilience and for the fiscal year 2023-24, provisional estimates indicate that the sector's growth rate stands at 1.4%[1].

The sector's current state owes its genesis to the history of the India economy during Independence in 1947. India inherited a fragile agrarian economy with low yields, food shortages and widespread poverty.[2] The 1960s ushered in India's Green Revolution, spearheaded by Dr M.S. Swaminathan and supported by the Indian Agricultural Research Institute. High-yielding varieties (HYVs) of wheat and rice, chemical fertilizers, pesticides, dependable irrigation and mechanized tools were introduced first in Punjab, Haryana and western Uttar Pradesh. These innovations transformed India into a self-sufficient food-grain producer by the mid-1970s.

This history is rooted in the nation's aspiration to provide food security for all. The production of staple crops, such as rice and wheat, is vital for food security in India, as these crops form the backbone of the nation's diet and provide essential calories and nutrients.

In FY23, the total production of food grains reached 329.7 million tons, an increase of 14.1 million from the previous year. Additionally, horticulture production hit a record high of 355.25 million tons, according to the third advance estimates, as per government data.

Although India achieved food security in cereals, the heavy reliance on chemicals and irrigation led to soil degradation, water-table depletion and ecological stress. Over time, concerns about monocultures, biodiversity loss and widening regional inequalities prompted calls for sustainable, diversified agriculture practices that balance productivity with resource conservation.[3]

India's agriculture is characterized by diversity, with performance varying significantly across different segments and states. As a major global cereal producer, India accounts for 11.6% of the world's total output, according to government statistics. However, crop yields in the country are considerably lower compared to those of other leading producers, underscoring the need for productivity improvements.

Horticulture as a growth driver

Since the 1990s, horticulture has emerged as a growth engine in Indian agriculture. India ranks first globally in production of bananas, mangoes, guavas, papayas

and lemons, and is a leading producer of vegetables like okra and spices such as chilies and ginger. Horticultural output now exceeds 330 million tons annually, outpacing cereals in growth rate due to high market value, export potential and government support for orchards, polyhouses and post-harvest infrastructure.[4]

Allied sectors—livestock, dairy, fisheries and aquaculture—have also seen rapid expansion under the "Blue Revolution" and dairy development programs. India is the world's largest milk producer, with output rising from 146 million tons in 2014–15 to 239 million tons in 2023–24, and over 8 crore farmers engaged in dairy activities.[5] Fish production doubled from 96 lakh tons in 2013–14 to 195 lakh tons in 2024–25, driven by inland fisheries and marine aquaculture initiatives.

India's horticulture sector is more productive and profitable than traditional agriculture, emerging as a fast-growing industry. This can be seen from the fact that India is also a leading exporter, shipping 343,982.34 MT of fresh grapes worth INR3,460.70 crore (US$ 417.07 million) globally in 2023-24. Key grape-growing states are Maharashtra, Karnataka, Tamil Nadu, and Mizoram. Maharashtra leads in production, contributing over 67% of total output with the highest productivity in 2023-24. Grape cultivation has significantly improved the livelihoods of Nashik farmers where export-quality grapes fetch higher prices (INR65-70/kg) than domestic markets. This economic upliftment has attracted rural youth to grape farming. Farmers have adopted advanced technologies like real-time monitoring systems to ensure optimal grape quality. The Nashik grape story shows how export-oriented agriculture, technology, and collective efforts can transform a region's socio-economic conditions.

India ranks second globally in production of rice and wheat, and is the top producer of millets, pulses and jute. In 2024–25, India's food-grain production reached record levels: rice at 1,490.74 lakh tons, wheat at 1,175.07 lakh tons and maize at 422.81 lakh tons. Oilseed output stood at 318.62 lakh tons (soybean 151.80, rapeseed and mustard 126.06, groundnut 118.96 lakh tons), while commercial crops like sugarcane and cotton produced 4,501.16 lakh tons and 306.92 lakh bales (170 kg each) respectively.[6] Agricultural exports have surged alongside output growth. In FY 2024–25, India exported US$49.4 billion worth of agriculture and processed food products, with processed foods accounting for 20.4% of agricultural exports—up from 13.7% in 2014–15. Key export commodities include rice, spices, cotton yarn, marine products and sugar, reaching over 120 countries globally. India's overall agricultural exports have crossed the INR4 lakh crore mark, driven by government incentives, quality improvements and brand promotions.

Despite growing influence the sector faced several challenges

India's agriculture sector is confronted with various interconnected challenges that have a negative impact on its growth and profitability. They include, prevalence of small and fragmented landholdings, which limits economies of scale and reduces the efficiency of resource utilization. The decline in soil quality, limited availability of top-notch resources, and ineffective farming techniques contribute to a further decrease in overall productivity. Additionally, the inefficient supply chains and inadequate storage infrastructure contribute to low farm gate prices and increased post-harvest losses. These challenges collectively limit the income potential of farmers and hinder the overall development of agriculture. In addition, Climate change poses an existential threat to India's complex agrarian system.

86% of Indian farmers operate on marginal and small landholdings

Climate change

Climate change affects crop yields, farmer profitability and overall sustainability. It is projected that rice and wheat yields would reduce by 20% by 2050 in the absence of climate adaptation measures, as government data shows. Overall, the agriculture sector has suffered a loss of $159 billion, or 5.4% of GDP due to climate stress, as per government information.

India is undergoing a structural transition in the agriculture sector.

Crop yields

1% temperature rise

→ 25% drop in yield

20% drop in rice and wheat yield by **2050**

Profitability

2% temperature rise and **7%** rainfall increase by

2100 →

8-12%
drop in farm productivity

Sustainability

60% rain-fed arable land susceptible to crop failure, soil erosion, salinity of coastal agriculture

There remains a substantial gap between the share of agriculture in employment and national incomes. The productivity gap between agricultural workers and non-agricultural workers continues to widen.

The gap between agriculture share of employment and GDP is also stark among India states. Farmers in states like Punjab and Haryana are relatively more prosperous, compared to the rest of India. Farmers in Maharashtra, Karnataka, Kerala, Tamil Nadu, and Gujarat as they exhibit a larger gap. These states have seen their secondary and tertiary sectors grow, with the share of agriculture in GDP falling below 10%.[7] States which spearheaded the Green Revolution have the greatest irrigation coverage. Increasing irrigation coverage is also critical to the goal of doubling farmers' income.

Marginal and small land holdings

On the socio-economic front, small land holdings averaging less than two hectares prevents Indian farmers to prosper. Fragmented plots prevent economies of scale, limit mechanization and impede access to finance and modern inputs. Without clear land titles, many farmers cannot secure institutional credit, leaving them dependent on high-interest informal loans and vulnerable to debt cycles.[8] Post-harvest losses exacerbate farmers' challenges.

Inadequate cold chain and storage infrastructure mean that 10–15% of perishable produce spoils before reaching markets.

Limited rural roads, electricity constraints and high transport costs further erode farm gate prices and reduce incomes, forcing many smallholders to sell at distress prices to middlemen.[9]

Price volatility and policy adequacy

Price volatility, uneven access to markets and a lack of value-addition facilities also weigh heavily on farmers. Minimum Support Price (MSP) procurement covers just a few crops and is geographically concentrated, leaving many regions without price assurance. Subsidy leakages, bureaucratic hurdles and delays in benefit transfers undermine the effectiveness of input subsidies and insurance schemes. On the policy front, while digital initiatives like e-NAM, Kisan Credit Cards and direct benefit transfers are expanding, adoption remains uneven, particularly among small, illiterate and older farmers.[10] Extension services struggle to keep pace with the rapid introduction of new technologies like drip irrigation, precision farming and agri-IT solutions.

Agritech and food processing innovation in India

India has witnessed a technology-driven transformation in agriculture and food processing. From precision farming tools to advanced processing lines, these innovations aim to boost productivity, reduce waste, and enhance quality across the value chain. Digital tools, automation, and bio-innovations have reshaped India's agri-ecosystem. As adoption spreads among smallholder farmers, these technologies promise sustainable growth, reduced waste, and enhanced livelihoods across rural India.[11]

Agri-tech players are harnessing a range of technologies to enhance operational efficiencies and build climate resilience. Numerous technologies, including climate smart solutions, precision farming, IoT sensors, AI/ML-based digital tools, are being introduced by agri-tech start-ups to drive efficiencies in the value chain.

Some innovations in the Indian agriculture sector

Area	Innovation	Description
Agriculture technology	**Precision agriculture and digital tools**	▪ Precision agriculture leverages GPS-enabled sensors, satellite imagery, and real-time analytics to monitor soil health, moisture levels, and pest outbreaks. ▪ Farmers can apply the exact amount of water, fertilizers, or pesticides needed for each field section, reducing input costs by up to 30% and boosting yields by 20–25%.[12]
	IoT and Smart Irrigation	▪ Internet of Things (IoT) devices—such as soil-moisture probes and weather stations—connect to cloud platforms, triggering drip or sprinkler systems only when needed. This smart irrigation approach conserves water in rain-fed regions, where 60% of cropped area remains dependent on monsoon rains. [13]

Area	Innovation	Description
	AI and Machine Learning	▪ AI-powered platforms analyze multi-year weather and yield data to forecast crop performance, recommend optimal sowing windows, and detect early signs of disease. Startups employing these models report up to 30% higher accuracy in pest predictions, enabling timely interventions and lowering chemical use. [14]
	Drones and Robotics	▪ Drones equipped with multispectral cameras survey large or fragmented farms to map stress zones, guide precision spraying, and even assist in seed planting. Meanwhile, robotic harvesters and automated weeding machines reduce labor drudgery and improve operational efficiency in high-value crops like fruits and vegetables.[15]
	Blockchain for supply chain transparency	▪ Blockchain pilots in agri-supply chains record every transaction—from farmgate pickup to retail delivery—guaranteeing traceability and reducing disputes. These distributed ledgers help exporters meet stringent international food-safety standards and build trust with global buyers.[16]
	Biotechnology and seed innovations	▪ Biotech advances have produced biofortified and climate-resilient seed varieties—rich in micronutrients and tolerant to drought or salinity. ▪ Over 70% of Indian farmers are projected to adopt these genetically enhanced seeds by 2025, aiming for higher yields with lower water and fertilizer inputs.
Food processing	**Automated sorting and packaging**	▪ Vision systems and robotics now sort fruits, vegetables, grains, and nuts at high speed, ensuring consistent quality and hygiene.
	Cold chain expansion	▪ Integrated cold-chain corridors and pack-houses under the Mega Food Parks Scheme have reduced post-harvest losses from 15% to under 5% for perishables.
	Robotics in meat and dairy	▪ Automated slaughter lines and IoT-enabled pasteurization units improve safety and extend shelf life in poultry and dairy processing plants.
	Novel preservation techniques	▪ High-pressure processing (HPP), pulsed electric fields, and edible coatings have emerged to maintain nutrient profiles without chemical preservatives.
Product innovation and process updates	**Functional beverages**	▪ The rise of cold-brew teas, protein-fortified shakes, and plant-based milks (almond, soy, oat) caters to health-conscious consumers and urban tastes.
	Ready-to-eat and millet snacks	▪ Quick-cook millet mixes, fortified cereals, and shelf-stable snacks tap into India's heritage grains while meeting modern convenience demands.
	Upcycling by-products	▪ Waste streams—fruit peels, vegetable pulp, and cereal husks—are converted into animal feed, bio-fertilizers, and nutraceutical ingredients, fostering a circular-economy ethos.

Government schemes and programs in the Agriculture sector

The Indian government has adopted a comprehensive approach to enhance agricultural productivity, ensure food security, improve farmer incomes, and promote sustainable practices across the sector. Agritech schemes fall either under the Center or under the States. Some of the most eminent government programs fall under five large buckets.

01

Price support and market interventions

- **Minimum Support Prices (MSPs):** Introduced in the mid-1960s to assure farmers a minimum price for their produce, particularly for staple crops like wheat and rice.
- **Public Distribution System (PDS):** Ensures subsidized food grains for a large segment of the population, procuring from farmers at MSPs.
- **Market Intervention Scheme (MIS) and Price Support Scheme (PSS):** Provide support for specific perishable and non-perishable commodities when prices fall below cost of production. [17]

02

Infrastructure and input support

- **Credit and Finance:** Expanded access to rural credit through institutions like NABARD and schemes like the Kisan Credit Card (KCC).
- **Irrigation Programs:** Initiatives like the Command Area Development Program (CADP) in 1974 aimed at optimizing water usage in irrigated areas.
- **Sub-Mission on Agricultural Mechanization (SMAM):** Focuses on making farm machinery and equipment accessible to small and marginal farmers, including the promotion of drone technology.
- **Agriculture Infrastructure Fund (AIF):** A medium-to-long-term debt financing facility for post-harvest management infrastructure and community farming assets. [18]

03

Farmer welfare and income support

- **Pradhan Mantri Fasal Bima Yojana (PMFBY):** Provides crop insurance to protect farmers against losses due to natural calamities and other unforeseen events.
- **Pradhan Mantri Kisan Samman Nidhi (PM-KISAN):** A direct income support scheme providing financial assistance to eligible landholding farmer families.
- **Formation and Promotion of new 10,000 FPOs:** Aims to form and promote Farmer Producer Organizations (FPOs) to enhance farmer bargaining power and market access.
- **Pradhan Mantri Kisan Maan-Dhan Yojana (PM-KMY):** A pension scheme for small and marginal farmers to provide social security in their old age.[19]

04

Soil health and sustainable farming

- **Soil Health Card (SHC) Scheme:** Provides farmers with information on soil nutrient status and recommendations for improving soil health and fertility.
- **Paramparagat Krishi Vikas Yojana (PKVY):** Promotes organic farming practices to enhance soil fertility and healthy food production without agro-chemicals.
- **National Mission on Sustainable Agriculture (NMSA):** Focuses on sustainable agricultural practices to conserve natural resources and minimize environmental impact.

05

Agricultural marketing and research

- **National Agriculture Market (e-NAM):** A pan-India electronic trading portal to connect existing APMC mandis, facilitating online trading and aiming for a unified national market.
- **Indian Council of Agricultural Research (ICAR):** Strengthened research and development efforts, developing HYVs, disease-resistant crops, and climate-resilient varieties.
- **National Agricultural Technology Project (NATP):** Focused on agricultural research and extension programs to bridge the knowledge gap for farmers. [20]

The Government of India operates several schemes, aimed to provide support farmers with technology, mentorship and incubation support for promoting innovation in the sector. The AgriStack is a Farmer-centric DPI to streamline services and scheme delivery to farmers. The RKVY: RAFTAAR scheme promotes development of agri-startups through incubation support. Per Drop More Crop (Pradhan Mantri Krishi Sinchayee Yojana) aims to enhancing water use efficiency through micro-irrigation.

Agriculture startups in India

The Indian agricultural landscape has seen a surge of innovation from agritech Startups in recent years. These companies leverage technology like AI, IoT, data analytics, and blockchain to address critical challenges in the agricultural sector, including supply chain inefficiencies, access to finance and markets, and crop management.[21] A description of some of the most eminent Startup players are as follows.

- A B2B marketplace transforming the fresh produce supply chain by directly connecting farmers with retailers, restaurants, and other businesses. They utilize AI and machine learning for demand forecasting and efficient logistics, aiming to reduce wastage and ensure fair prices for farmers.
- An integrated platform offering a comprehensive range of services to farmers, including inputs (seeds, fertilizers, etc.), crop advisory services, financial assistance, and market linkages, empowering small and medium-sized farmers. They leverage AI and mobile technology to provide tailored advice and connect farmers to markets and financial services.
- A Startup that connects farmers with expert advice and quality agricultural inputs through its mobile application. They offer products like seeds, fertilizers, pesticides, and tools, alongside agronomy consultation, weather updates, and personalized recommendations.
- A tech Startup which provides AI-powered farm management and traceability solutions to farmers and agribusinesses globally. It utilizes big data and AI for precision farming, enabling real-time crop monitoring, predictive analytics, and enhanced yield management.
- This supply chain optimization Startup focuses on optimizing the agri-food supply chain, connecting farmers directly with businesses and consumers for fresh produce, dairy, and other essentials. They prioritize efficiency, reduced food waste, and fair pricing through their technology-driven platform.
- A B2B digital marketplace for agricultural commodities that connects buyers and sellers across India. This Startup improves transparency in the agricultural value chain, provides financial support to

businesses, and facilitates efficient transactions and logistics.

- An AI Startup which specializes in AI-driven quality assessment of agricultural produce, using computer vision and image recognition technology. Their solutions help farmers, food processors, and businesses grade and sort products more accurately, reducing losses and improving market value.
- An AI Startup utilizes an AI-powered IoT platform with on-farm sensors to provide real-time data on growing conditions. Farmers receive farm and crop-specific warnings and recommendations via mobile in local languages, leading to better resource management, increased yields, and sustainable practices. It has also helped farmers save billions of liters of water.
- An online platform and mobile app delivers personalized farm management solutions. They offer agronomy advice, weather and soil analysis, cost analysis, and access to agricultural inputs to help farmers improve cultivation practices and increase yields. Recently, this Startup has transitioned to a B2F (Business to Farmer) model to better serve farmers with technological support.
- A digital marketplace for farmers offers a wide range of agricultural inputs, expert advice, and smart farming tools. They provide products like seeds, fertilizers, and pesticides, along with digital resources for crop management and technical support. It also recently partnered with Microsoft to develop Kisan Vedika, addressing farmers' queries in regional languages.
- This Startup aims to reduce agricultural waste and optimize supply chain networks by connecting farmers directly with businesses through a Farm-to-Business (F2B) model. It utilizes AI-based demand prediction systems and has partnered with major retailers.
- A bioscience company leveraging nature's intelligence and AI to provide sustainable agritech products and solutions, with research in biomaterials and biocare. They focus on controlling the entire agricultural cycle, from seed to harvest.
- An AI-based quality assessment solutions for agricultural produce, using advanced analytics for informed decision-making by farmers and buyers. Their technology enhances quality control and traceability, boosting the credibility of Indian agricultural products.
- An AI-driven platform providing personalized agronomy advice, including recommendations on crop health, fertilizers, and pest control. They also offer a range of agri-inputs and services like warehousing and inventory management.

The need for urgent mitigation of Agriculture sector challenges

Looking ahead, boosting agricultural resilience requires multifaceted interventions: consolidating land through cooperative models, scaling up micro-irrigation and renewable energy-driven water pumps, expanding cold chains and pack-houses, and incentivizing crop diversification beyond cereals. Strengthening farmer producer organizations, enhancing market linkages via e-commerce platforms, and investing in climate-smart varieties can help buffer smallholders against climatic and market shocks. At the same time, modernizing food processing is crucial for linking farm surplus to urban demand, reducing waste and generating rural employment. Expansion of cluster-based food parks, contract farming, and PLI schemes for processed foods can elevate India's position in global agri-value chains.

From its ancient origins to the Green and Blue Revolutions, India's agriculture has made remarkable strides in output and self-sufficiency. Yet, the sector stands at a crossroads, buffeted by climate change, structural constraints and market uncertainties. Addressing land fragmentation, upgrading infrastructure, and fostering sustainable practices will be key to securing the livelihoods of 150 million farm families and ensuring food security for a growing nation.

India's clean energy transformation:

Renewable energy and electric mobility revolution

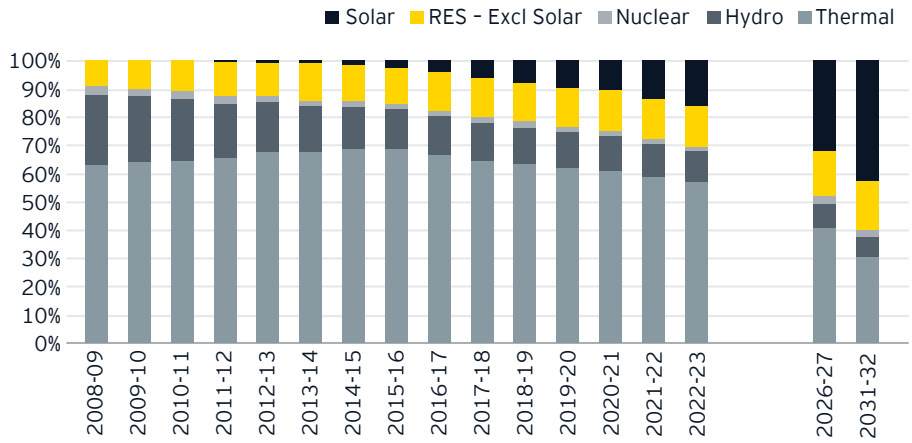
02

CHAPTER 02

India's energy agenda includes ambitious renewable energy targets and a rapidly evolving electric mobility ecosystem. With projected power demand expected to rise to 708 GW by 2047, necessitating a fourfold increase in installed capacity to 2,100 GW[22] requires a balance between meeting higher demand with sustainability goals. India's clean energy transition strategy therefore encompasses renewable energy expansion, green hydrogen capacities and electric vehicle adoption.

The Central Electricity Authority's National Electricity Plan 2022-32 projects a consistent upward trend in peak electricity demand, with projections rising from 203,115 MW in 2021-22 to 366,393 MW in 2031-32 (CAGR of 6.1%[23]). This growing demand, coupled with India's commitment to achieving 500 GW of renewable capacity by 2030[24] necessitates a fundamental restructuring of the energy infrastructure and economic model.

Installed & Expected Electricity Generation Capacity (GW)



Source: IBEF

Renewable energy: The foundation of India's energy transition

Solar energy: Harnessing India's natural advantage

With 300 days of sunshine annually and solar irradiance ranging from 4-7 kWh/m²/day, India receives 2,300-3,200 sunshine hours annually, offering an estimated potential of 5,000 BU of electricity

per year or approximately 2,500 GW of capacity at current efficiency levels (CGIAR Research).

The solar sector has demonstrated remarkable growth over the past decade, with installed capacity growing at a CAGR of 36.5% over the past 11 years, as per an EY report on energy transition. This reflects India's role in the global solar energy transition, supported by government policies and increasing uptake of solar projects across various sectors.

India's National Electricity Plan aligns with the country's commitment to the Paris Agreement and outlines an ambitious roadmap targeting 280 GW of solar power capacity by 2030 as part of the broader 500 GW renewable energy target, as per a government announcement. This solar capacity expansion is supported by several key government initiatives that have proven instrumental in driving sector growth.

Solar Parks and Ultra Mega Solar Power Projects, initiated in 2014, established the foundation for large-scale solar deployment, creating dedicated infrastructure zones that enabled efficient land acquisition, grid connectivity, and project development processes, significantly reducing the complexity and cost of solar installations.

The PM Surya Ghar Muft Bijli Yojana, launched in 2024, along with the Pradhan Mantri Suryoday Yojana, has given momentum to the target of 10 million household rooftop solar installations, democratizing access to solar energy and reducing transmission losses through distributed generation.

Wind energy: Capturing India's atmospheric resources

India ranks fourth worldwide with an installed capacity of 46.42 GW, reflecting the maturing wind technology deployment, as per government data.

The government has set an ambitious target of 140 GW[25] renewable capacity from wind by 2030, including 30 GW from offshore wind development. In 2023 alone, India commissioned over 2.8 GW of onshore wind capacity, demonstrating consistent progress toward these targets despite global supply chain challenges and technological transitions, as per government data. The 2023 National Repowering Policy represents a significant strategic initiative aimed at modernizing aging wind turbines and enhancing overall sector efficiency.

Offshore wind development is the next frontier. The government's 4 GW seabed leasing plan, backed by INR7,453 crore in Viability Gap Funding, aims to accelerate capacity expansion in offshore areas along India's extensive coastline. These offshore projects offer higher capacity factors and reduced land acquisition challenges compared to onshore developments.

Hybrid solar-wind projects have emerged as an innovative approach to optimize renewable energy generation and grid integration. These projects leverage the complementary generation patterns of solar and wind resources, with wind generation often peaking during evening hours when solar generation decreases, providing more consistent renewable energy output throughout the day. By September 2024, operational hybrid capacity had grown to approximately 7.7 GW, with approximately 30 GW more in the planning or implementation stages.

Source: Fourth Partner Energy

Infrastructure development in key wind-rich states like Gujarat and Tamil Nadu continues to support sector growth through enhanced transmission connectivity, port facilities for component transportation, and specialized manufacturing zones for wind equipment production.

Battery energy storage and real-time integration

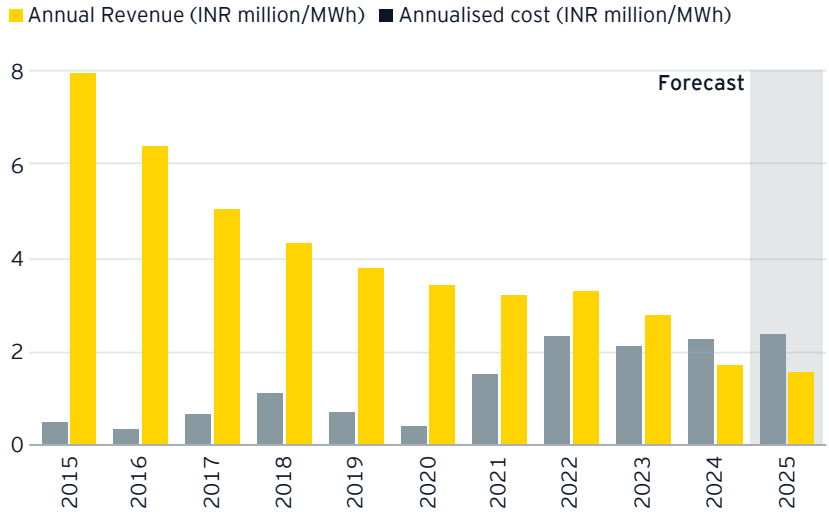
Integration of battery energy storage systems (BESS) with renewable energy projects is important for grid stability and reliability as renewable energy penetration increases. Energy storage investments have risen dramatically from just 1% of deal volume in 2017 to 9% by 2024[26], with lithium-ion batteries dominating.

BESS support grid flexibility and reliability by allowing frequency regulation, voltage support, peak shaving, and renewable energy time-shifting to address the intermittency challenges in solar and wind generation.

Hybrid systems combine solar, wind and storage components to provide round-the-clock renewable power delivery. These integrated systems can participate in various electricity markets while providing grid services that enhance overall system reliability.

Smart grid integration is the next evolutionary step in battery storage deployment, enabling dynamic response to grid conditions and optimized energy management across distributed generation resources. Advanced battery management systems can coordinate with grid operators to provide real-time balancing services while maximizing economic returns for project operators.

Batteries installed in India post-2024 are projected to be profitable[27], driven by falling battery storage costs (expected to decline approximately 60% by 2030), rising renewable energy penetration and supportive government tenders under the National Green Hydrogen Mission and renewable integration schemes. Energy Storage Systems (ESS) inclusion in renewable energy tendering has steadily increased from 16% to 43% since 2019[28].



Source: Revenue estimated for best-in-class BESS performance using Ember's BattMan model and IEX market data, 2024.[29]

India's requirement for energy storage capacity is projected to reach 73.93 GW by 2031-32 with 26.69 GW from Pumped Storage Plants (PSP) and 47.24 GW from Battery Energy Storage Systems (BESS). This opens up opportunities for battery manufacturers, system integrators, and project developers but will also require advances in manufacturing capacity, supply chain development, and technical capabilities.

Source: Ember

Green hydrogen: The future fuel economy

Green hydrogen represents a transformative opportunity for India to reduce its dependence on fossil fuels, largely imported, while positioning itself as a global hub for clean energy exports. The government has allocated US$2.4 billion[30] in subsidies to renewable hydrogen projects through the National Green Hydrogen Mission. For the financial year 2025-26, the Union Budget allocated INR600 crore[31] to the National Green Hydrogen Mission.

The ambitious target of producing 5 MMT (million metric tons) of green hydrogen annually by 2030 requires scaling up industrial capacity,[32] additional 125 GW of dedicated renewable capacity, robust water logistics infrastructure and domestic electrolyzer manufacturing capabilities. Water availability and quality become critical factors in project site selection, particularly in water-stressed regions where competition for water resources could limit project viability. Development of domestic electrolyzer manufacturing capabilities represents both a strategic opportunity and a necessity for India's green hydrogen ambitions.

Export opportunities and market development

The disparity between India's potential green hydrogen production capacity and domestic consumption creates opportunities for export market development. Currently, 90% of hydrogen consumption in India serves captive purposes, resulting in a relatively small tradeable market that limits economies of scale development.[33]

Until robust domestic demand is established, exporting represents a vital strategy for achieving the economies of scale necessary for cost reduction and technological advancement. The EU, Japan, and South Korea are major import markets due to their aggressive consumption targets and limited domestic production capabilities. There are media reports of several major projects in India securing offtake agreements with international buyers.

India's green hydrogen sector is rapidly transitioning from pilot projects to global trade collaborations, with large-scale export agreements and industrial tie-ups reinforcing commercial viability and providing revenue certainty for large-scale project development. A proposed 1.2 MTPA green hydrogen and ammonia project has secured an offtake agreement with a corporation in Japan, exemplifying an emerging export model. Another entity has entered into foreign agreements to export green hydrogen. An agreement

for renewable ammonia supply has been signed by a production facility, integrating green hydrogen into established chemical value chains.

India could potentially capture 10% of the global green hydrogen market, translating to approximately 10 MMT of green hydrogen and green ammonia exports annually, as per government estimates.

Industrial applications and domestic market development

The fertilizer industry, currently reliant on imported natural gas and ammonia, represents one of the most promising domestic applications for green hydrogen in India.

The Ministry of New and Renewable Energy increased the annual production capacity for green ammonia under Mode 2A of the SIGHT scheme from 550,000 to 750,000 tons per year in June 2024. In August 2025, the first SECI auction under Mode 2A resulted in a discovered price of just INR55.75 per kg, only 10.1% higher than grey ammonia, signaling a potential shift toward greater price parity[34]. Fourteen fertilizer plants identified in the Solar Energy Corporation of India's tender will consume this green ammonia, creating a guaranteed domestic market for green hydrogen production.

This transition to green ammonia in fertilizer manufacturing supports India's net-zero vision while reducing import dependency of critical agricultural inputs. The shift could significantly insulate the country from global price volatility in fertilizers and natural gas, enhancing food security and agricultural competitiveness.

Steel production represents another major opportunity for green hydrogen adoption, with several major steel producers exploring hydrogen-based direct reduction processes as alternatives to coal-based production. These industrial applications provide the scale necessary for green hydrogen cost reduction while supporting India's industrial decarbonization objectives.

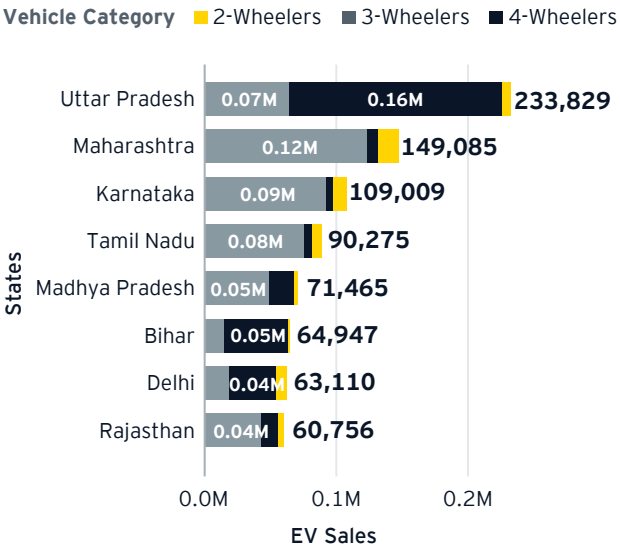
Until robust domestic demand for green hydrogen in India is established, exports can help achieve economies of scale necessary for cost reduction and technological advancement.

Electric vehicles: Transforming India's mobility landscape

EV adoption in India has accelerated across all vehicle segments, with EV sales expected to reach 12.8 million units annually by FY30 according to the India Energy Storage Alliance (IESA), achieving an overall vehicle penetration rate of 28%. This growth trajectory reflects the convergence of government policy support, technological advancement, and changing consumer preferences driven by economic and environmental considerations.

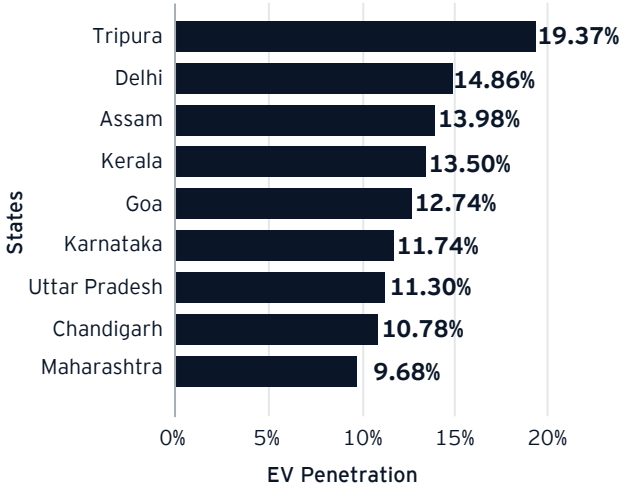
EY Sales by State

Describes state-wise sales of all EV vehicular categories



EV Penetration by State

Describes state-wise EV Penetration (EV Sales ÷ overall sales)



Source: EV Vahan Dashboard, 2025 data

Two-wheelers dominate India's EV landscape, holding approximately 90% market share by vehicle type. The sales of electric two-wheelers have increased approximately five times from FY21 to FY24.[35] Large private fleet operators control most of the market share, representing the emergence of organized fleet operations and importance of operational scale in achieving cost competitiveness.

Three-wheeler EV sales have grown at 45% CAGR (FY20-FY24), making India the largest three-wheeler electric market globally, surpassing China in 2023. The lower total cost of ownership and supportive incentives under the FAME II scheme have been instrumental in achieving this market leadership position.

Electric four-wheelers represent the segment with the highest growth potential despite currently having the lowest penetration compared to two-wheelers and three-wheelers. Sales have grown approximately 150% over the last five years, driven by purchase incentives, supply-side support through PLI schemes, tax advantages, and comprehensive awareness campaigns.

Policy framework and government support

The central and state governments' comprehensive policy framework and support has been crucial in accelerating EV adoption, including subsidies, GST reduction and exemptions from permit requirements.

State governments have responded enthusiastically to central government initiatives, with states like Uttar Pradesh and Tamil Nadu offering 100% waivers on registration fees for strong hybrid and plug-in hybrid EVs. The increased demand for EVs provides manufacturers opportunities to scale production volumes.

The FAME II scheme has been particularly effective in supporting both demand-side adoption and supply-side development. Government investment

of US$125.6 million under FAME II has spurred increases in charging infrastructure while providing purchase incentives replace with (World Bank).

The recently announced PM e-drive scheme allocates INR2,000 crore to support deployment of 72,300 public charging stations, with 48,400 stations specifically designated for two-wheelers and three-wheelers. The Government launched PM e-Bus Sewa scheme in August 2023 to boost public transport in cities. With a budget of INR20,000 crore (provided by the central government) for deploying 10,000 electric buses under the Public-Private Partnership (PPP) model[36], the scheme focuses on making urban travel cleaner and more efficient. These targeted approaches recognize the different charging requirements and usage patterns across vehicle segments.

Manufacturing investments and industrial development

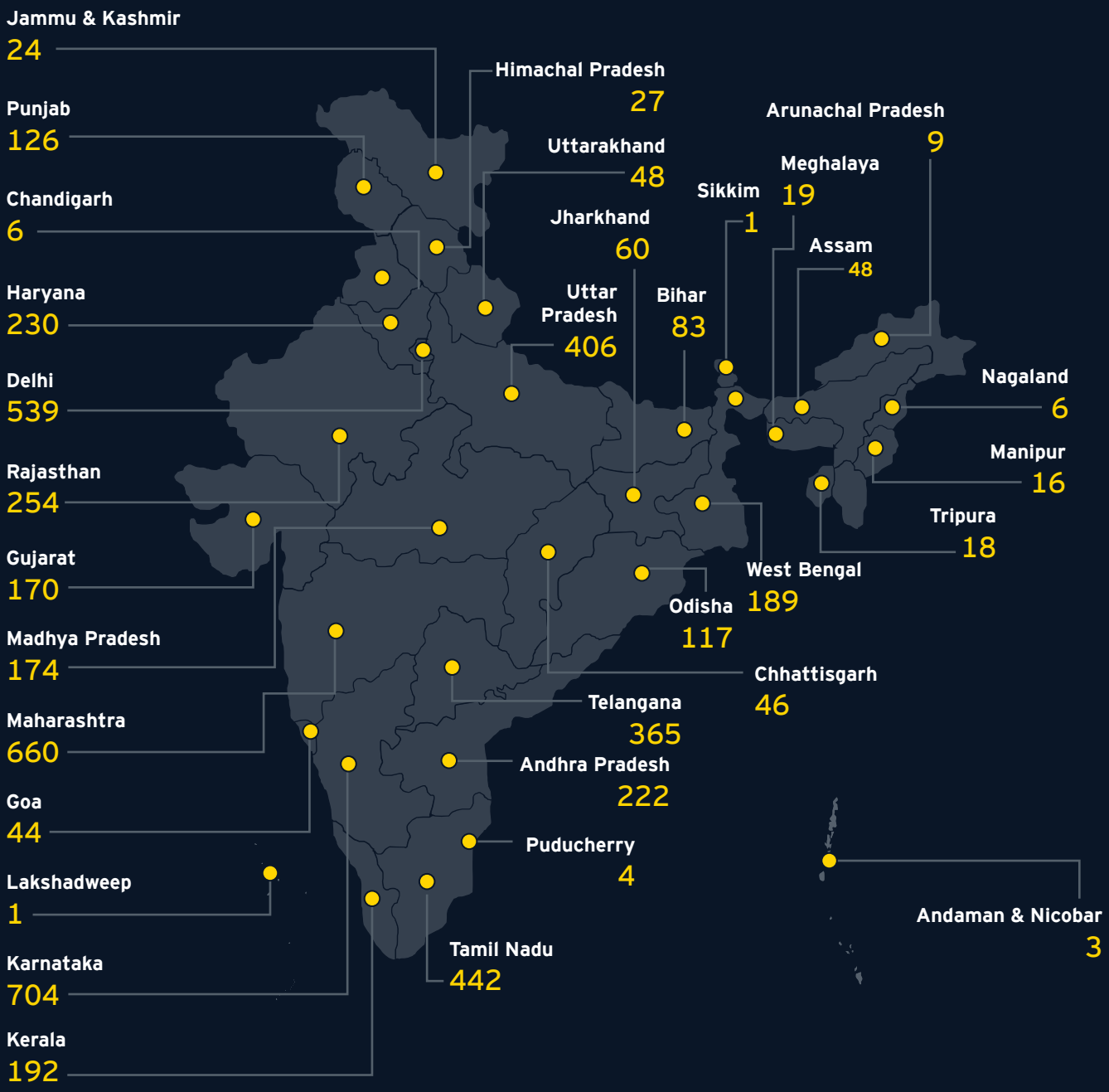
The EV manufacturing sector attracts domestic and international investment, reflecting both market opportunities and government incentives designed to build India's position as a global EV manufacturing hub. A Swedish company planned a US$1 million investment through its Indian subsidiary to establish a dedicated manufacturing facility in Pune in June 2024. A leading Indian electric two-wheeler manufacturer has committed over INR2,000 crore to establish a manufacturing unit in Maharashtra. This facility will produce electric two-wheelers and battery packs, expanding the company's manufacturing footprint beyond its existing facilities in Hosur, Tamil Nadu.

Battery technology and energy storage solutions

Battery-as-a-Service: Revolutionizing EV economics

Battery-as-a-Service (BaaS) models have emerged as a critical innovation in addressing the high upfront costs associated with electric vehicle adoption, particularly in commercial applications like buses and fleet operations. Since batteries account for 40% to 50% of an electric vehicle's cost, BaaS models that allow operators to lease rather than purchase batteries significantly reduce initial capital expenditure requirements[10].

Total Number of Public EV Charging Stations



Source: Ministry of Power, Vahan dashboard [39]

The operational benefits of BaaS extend beyond cost reduction to include minimized vehicle downtime through battery swapping stations and professional battery lifecycle management. For India's vast network of over 2 million buses operated by more than 20,000 private operators, establishing a standardized and interoperable battery ecosystem becomes essential for seamless operations across different manufacturers and service providers.

Usage-linked leasing solutions are being adapted for Indian conditions to support the transition to electric mobility. These models align battery costs with actual vehicle utilization, making electric vehicles more attractive for commercial operators with varying usage patterns.

A major EV charging infrastructure company in India has introduced a battery passport system that enables comprehensive Battery-as-a-Service offerings for commercial vehicles including electric buses and trucks. This system tracks battery lifecycle through comprehensive data collection at every stage, enabling optimized maintenance schedules and end-of-life management.

The most prevalent business model adopted by State Transport Undertakings (STUs) is the gross cost contract (GCC), which eliminates upfront capital expenditure by STUs while providing competitive per-kilometer rates. Service providers can operate competitively under GCC models due to revenue and tenure assurance provided by STUs, creating sustainable business frameworks for large-scale electric bus deployment.

Battery recycling and circular economy

Battery waste management must represent a comprehensive framework for creating a circular economy around battery materials. The Battery Waste Management Rules 2022 mandate that 90% of discarded battery materials must be recycled and recovered by 2026, establishing clear targets for resource recovery. Furthermore, these rules require that 20% of recycled materials be used for manufacturing new batteries by 2030, creating demand for recycled content and incentivizing the development of sophisticated recycling technologies and processes. The demand from end-of-life batteries is estimated to reach 128 GWh by 2030[37], with 46% (59 GWh) originating from EVs alone—implying a required 60-fold increase in capacity.

An Indian startup specializing in battery recycling and resource recovery extracts rare earths and critical minerals from "black mass" (a byproduct of used lithium-ion batteries). These recovered materials are reused in EV batteries and defense applications. Another startup in Tamil Nadu is recycling e-waste—including lithium, cobalt, nickel, graphite—and refining them into battery-grade materials.

India's dependence on imported battery materials creates vulnerability to supply chain disruptions and price volatility. The battery recycling sector addresses both environmental concerns and resource security issues.

Charging infrastructure: Enabling mass EV adoption

India's EV charging infrastructure has experienced remarkable expansion, with the number of public charging stations increasing nearly ninefold from 1,800 in February 2022 to more than 26,300 as of early FY 2025.[38] This rapid deployment reflects both government policy support and private sector investment in anticipation of growing EV adoption rates.

The Charging Point Operators (CPOs) in India have developed ambitious expansion plans targeting over 100,000 EV charging stations by FY27. The operators have formed strategic partnerships with B2B fleet players to ensure utilization rates while collaborating with real estate players to access key locations for charging infrastructure deployment.

Most current public and semi-public chargers are slow chargers that primarily serve two-wheelers and three-wheelers, which rely predominantly on Alternate Current (AC) slow charging and battery swapping technologies. The market remains fragmented with multiple players operating across AC and DC charger solution categories, indicating opportunities for consolidation and standardization.

Advancement in battery technology and the growth of fast charging capabilities will further fuel demand for efficient charging infrastructure that can support rapid vehicle turnaround times for commercial applications and convenient charging experiences for private vehicle owners.

Government policy and infrastructure development

The New EV Charging Policy announced by the government establishes ambitious targets for charging infrastructure density and accessibility--at least one charging station per square kilometer by the end of this decade. Major highways and expressways may have fast-charging stations every 100 kilometers, enabling long-distance travel and reducing range anxiety concerns. The policy also ensures that electricity costs for these charging stations remain below the average cost of supply (ACoS) until March 2028.

Central government subsidies are complemented by state government incentives designed to accelerate the development of modern EV charging infrastructure. This multi-level policy approach ensures comprehensive coverage while allowing states to tailor incentives to their specific market conditions and EV adoption patterns.

Innovations

Regional investment clusters and innovation hubs

Bengaluru has emerged as India's premier hub for e-mobility startups and EV innovation, hosting several of the country's most successful electric vehicle companies. The city's established technology ecosystem, skilled workforce, and venture capital presence create an ideal environment for EV innovation and scaling. For example, an Indian EV manufacturer has large-scale Gigafactory plans for two-wheelers, aiming to establish India as a global manufacturing hub for EVs. The company's integrated approach to manufacturing, software development and charging infrastructure exemplifies the comprehensive business models emerging in the sector. An EV startup manufactures electric scooters and smart charging infrastructure while focusing on premium market segments and advanced connectivity features. The company's emphasis on smart technology integration demonstrates the evolution toward connected mobility solutions.

Delhi-NCR is a major center for renewable energy generation projects and corporate headquarters for large-scale renewable energy companies. This concentration reflects the region's proximity to policy-making institutions and established industrial infrastructure. A leading renewable energy company with extensive solar and wind project portfolios has scale and operational experience, providing valuable insights into large-scale renewable energy development and grid integration challenges.

An independent power producer focuses on large-scale solar generation projects that serve utility-scale markets.

Mumbai's role as India's financial capital makes it a natural center for clean energy financing and investments. The city hosts several major corporations that have operational and financial commitments to the sector. One of India's leading power companies is expanding into solar, wind and green hydrogen sectors, demonstrating the integration of renewable energy with established industrial operations. Major global financial institutions channel capital through their India teams based in Mumbai. These institutions provide the large-scale funding necessary for renewable energy and green hydrogen project development while bringing international expertise and standards to Indian operations.

Production-Linked Incentives (PLI) and manufacturing development

The PLI Scheme represents a strategic approach to building domestic manufacturing capabilities across critical clean energy technologies. The PLI framework spans 14 major sectors, with a total incentive outlay of around INR1.97 lakh crore[40].

The government has launched targeted PLI programs for battery manufacturing, electrolyzer production, and green hydrogen production, creating comprehensive support for the entire clean energy value chain. To date, the scheme has attracted INR67,690 crore in committed investments, and generated over 28,800 jobs.[41]

The Advanced Chemistry Cell PLI scheme, worth INR18,100 crore, specifically targets battery manufacturing to build India's capabilities in this critical technology area. This investment addresses both domestic market requirements and export opportunities while reducing dependence on imported battery technologies.

Electrolyzer manufacturing PLI schemes aim to scale hydrogen production capabilities by supporting domestic equipment manufacturing. These incentives are crucial for achieving cost-competitive green hydrogen production while building export capabilities in electrolyzer technology.

Green hydrogen and ammonia production PLI schemes focus on enhancing export competitiveness

by supporting large-scale production facilities that can achieve economies of scale necessary for international market competition.

Innovation in business models and financing

One platform exemplifies innovative approaches to renewable energy financing and market development. By supplying round-the-clock renewable power to a resources group and other commercial and industrial consumers, it demonstrates the integration of renewable energy generation with assured industrial demand.

The integration of renewable energy supply with industrial demand represents a critical innovation for scaling green hydrogen production, as it provides the long-term power purchase agreements necessary for project financing while ensuring that renewable capacity additions are matched with corresponding demand growth.

Transportation applications and hydrogen mobility

India has initiated five pilot projects under the National Green Hydrogen Mission specifically focused on transportation applications, deploying 37 hydrogen-powered vehicles across diverse operational environments, providing comprehensive real-world testing of different hydrogen mobility technologies.

The government has allocated INR208 crore (US$25.06 million) for these pilot projects, which include both vehicles and supporting infrastructure development. Nine hydrogen refueling stations are being established as part of these pilots, with operations expected to commence within 18-24 months.

Central and state government subsidies are accelerating the development of modern EV charging infrastructure. States can tailor incentives to specific market conditions and EV adoption patterns.

Technology advancement and R&D

Energy storage technology advancement focuses on improving battery performance, reducing costs, and enhancing grid integration capabilities. The growth of smart grid integration enables dynamic response to grid conditions and optimized energy management across distributed generation resources.

Advanced battery management systems coordinate with grid operators to provide real-time balancing services while maximizing economic returns for storage operators. These systems enable storage assets to participate in multiple revenue streams including energy arbitrage, frequency regulation, and capacity markets.

The development of hybrid renewable energy systems combining solar, wind, and storage components enables round-the-clock renewable power delivery while providing grid services that enhance overall system reliability. These integrated systems represent the evolution toward dispatchable renewable energy that can replace conventional thermal generation.

Recommendations

India stands at the cusp of a transformative clean energy and electric mobility revolution. The country now needs to leverage its rapidly growing renewable energy capacity while increasing strategic investments in green hydrogen and expanding electric mobility market by continuing and strengthening coordinated efforts across innovation hubs, regional industrial clusters, and manufacturing ecosystems. Some of the steps that India should take to emerge as a leader in clean and sustainable energy are:

- Scaling renewable capacity aggressively to meet the target of 500 GW of non-fossil fuel electricity by 2030, a goal India is advancing towards ahead of schedule, having crossed 50% non-fossil capacity already.
- Expanding green hydrogen production under the National Green Hydrogen Mission, targeting 5 million tons per year by 2030 with planned investments exceeding INR8 lakh crore and creation of over 600,000 jobs.
- Accelerating electric mobility adoption supported by government schemes like FAME, aiming for 30% EV market share by 2030 and substantial employment generation.
- Strengthening the domestic manufacturing ecosystem, especially for battery technologies, electrolysers, and solar/wind components, supported by investment-friendly policies and 100% FDI under the automatic route.
- Promoting circular economy practices and sustainable infrastructure development to enhance resource efficiency and lifecycle emissions reduction.
- Sustaining policy frameworks that stimulate private sector investment, innovation, and long-term demand through renewable purchase obligations, tendering for clean power, and transmission charge waivers.
- Facilitating energy transition in hard-to-electrify sectors through green hydrogen and other clean fuels.
- Building India as a global exemplar for inclusive economic growth driven by clean, secure, and affordable energy.

This holistic and integrated approach, backed by strong policy commitments and growing markets, is essential to accelerate India's energy transition, meet its net-zero by 2070 target, and position the country as a global leader and blueprint in sustainable energy and electric mobility.

Innovations shaping Indian healthcare:

Policy to practice

03

CHAPTER 03

Overview of Indian healthcare

India's healthcare narrative goes beyond merely treating diseases; it focuses on creating a healthier future for more than a billion people. A complex interplay of factors has moulded the progress made so far and the future steps. Affordability, accessibility, equity and social inclusion are as important as coverage, quality, use of technology, innovation, skilling and governance. The public and private sector are both active participants in this area of national importance.

In the past, developments such as the first primary mediclaim policy being introduced in late 1980s and liberalization in 1991, soon followed by entry of private sector in insurance and expansion of private healthcare groups driven by domestic and international investments have been milestones in the growth of healthcare in the country. Legislation – public health and hospitals are largely states' responsibilities while social security and social insurance are in the concurrent list – is designed for uniformity and adaptability.

The evolving policy framework has been actively charting the path of healthcare in India. From the foundations set in primary healthcare by the first National Health Policy (NHP) in 1983 to NHP 2002, followed by Ayushman Bharat-Pradhan Mantri Jan Arogya Yojana (PM-JAY) in 2018) and the National Digital Health Mission (NDHM, subsequently ABDM) in 2020, represent the evolution of modern healthcare towards efficiency and effectiveness.

The Indian healthcare sector has a very clear vision: high-quality, affordable, accessible and comprehensive healthcare. The government's policy focus, India's large population, growing economy, technological innovations and increasing demand are fueling the next phase of developments.

Indian healthcare industry 2025

Infrastructure and workforce

Doctor-population ratio: 1:811 (better than WHO 1:1000)

- 6 million+ healthcare workers

Accessibility and inclusion

65% population in rural areas

- Public healthcare use (42% to 46% from 2020- 2022)

Government policies and regulatory frameworks

Ayushman Bharat: 100 million+ families covered

- ABDM: 740 million+ digital health IDs

Technology and innovation

AI in healthcare: US$1.6 billion by 2025 (CAGR 40%+)

- Telemedicine (e-Sanjeevani) in rural India

The Indian healthcare sector is predicted to have a market share of US$120-130 billion by FY25, growing at a CAGR of 11%-12% between 2020 and 2025, setting the stage for future expansion. The hospital market itself is estimated to be worth US$100 billion by 2032, nearly the double of ~US$ 50-55 billion in 2025 (CAGR of 11%-12%). However, to achieve the intended aim, the significant efforts targeted at healthcare, including a budgetary outlay of INR99,858 crore (US$11.50 billion) in the Union Budget 2025-26,[42] have to also overcome several challenges.

Weaknesses in the healthcare ecosystem

Building healthcare systems that are sustainable, inclusive and reach 1.4 billion people is a huge and complex endeavor. Even with the tremendous advances in healthcare technology, infrastructure and delivery, there are multiple challenges, including inequitable distribution, accessibility, rising out-of-pocket expenditure, and lack of infrastructure. Also, there is huge variance among states in level of healthcare services. Considering the SDG India Index FY 2023-24, Uttarakhand and Kerala are the top performing states with a score of 84 and 80 respectively, while Jharkhand and Bihar fare lower. Health indicators like maternal mortality rate, immunization, life expectancy and density of health workers were considered[43].

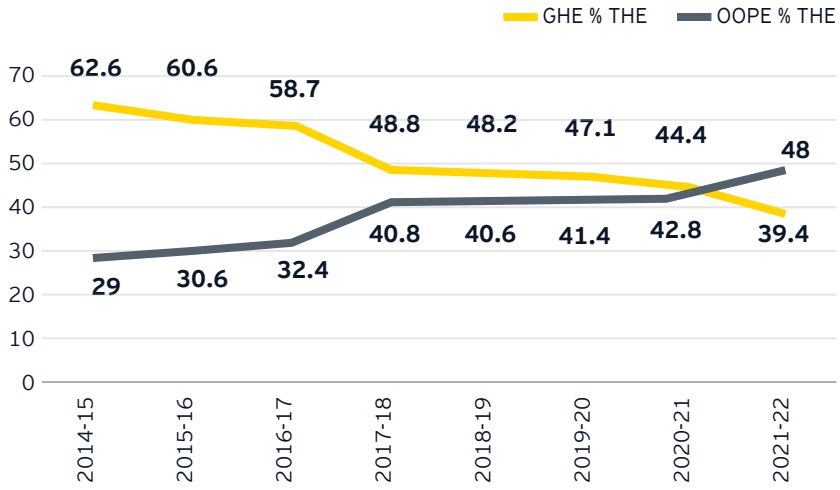
Even though the estimated doctor-population ratio is 1:811, which is higher than the WHO standard

Central and state government subsidies are accelerating the development of modern EV charging infrastructure. States can tailor incentives to specific market conditions and EV adoption patterns.

of 1:1000[44], and more than 6 million healthcare workers as of FY24, there is stark variation in quality and accessibility, particularly in rural India[45]. Notably, there is higher concentration of healthcare services in urban areas though use of medical care is increasing in both urban and rural areas.

According to the National Health Mission survey, around 65% of Indians live in rural areas. People using public health institutions in these areas has increased from 41.9% to 45.7% between 2016 and 2021[46]. Yet, there is heavy dependence on private healthcare services and limited insurance penetration. While out-of-pocket expense has decreased from FY 2014-15 to FY 2020-21 by some estimates, gaps in infrastructure and insurance continue to keep it high[47]. Out of the total health expenditure, Indian household expenditure on private health insurance has increased from 7% to 7.3% from FY 2019-20 to FY 2020-21[48].

Government Health Expenditure (GHE) and Out-Of-Pocket Expenditure (OOPE) as % of Total Health Expenditure (THE)



Source: https://www.pib.gov.in/PressNoteDetails.aspx?NoteId=153407&ModuleId=3

All healthcare service providers aim to improve patient care and enable smooth patient journey. To improve end-to-end patient interaction, the industry is already utilizing digital, scalable solutions and process advancements and emerging technologies such as AI play a big role in this. The global healthcare AI market is estimated to be worth US$39.25 billion in 2025[49]. AI has the potential to revolutionize the patient journey and make healthcare more patient-centered, accessible, and efficient as it develops.

Government initiatives drive innovation

The digital push across primary, secondary, and tertiary care programs from the central and state governments continues to drive large-scale innovation with far-reaching impact in healthcare in India. Telehealth facilities, unified cloud-based data systems, unique digital identities for individuals, automation, interconnected systems and step-by-step digitalized processes are defining the next era of healthcare services in India.

The impact of innovation seen during COVID in the success of CoWIN has led to the emergence of the vaccine supply chain Electronic Vaccine Intelligence Network (eVIN).

Policies created to support innovation In the healthcare sector include the National Medical Devices Policy 2023, which aims to support domestic manufacturing's capabilities in newer technologies to make medical devices affordable and improve clinical outcome. This would lower the out-of-pocket expenditure on diagnostics and thus the long-term cost of disease burden. It also aims to develop an ecosystem of innovation for technology-driven devices for preventive, promotive, diagnostic, curative, rehabilitative, geriatric and palliative healthcare.

Production-Linked Incentive (PLI) Scheme, among others, has also given a boost to the sector. The Promotion of Research and Innovation in Pharma MedTech Sector (PRIP) scheme, 2023 aims to change the country's pharma MedTech sector to innovation-based growth from a cost-based focus.

The National Health Policy, 2017 lays emphasis on preventive and promotive healthcare, research on social factors affecting health, health issues that receive less attention, and discovery and innovation in drugs and devices.

A strong foundation of public R&D institutions such as Council of Scientific & Industrial Research, Department of Biotechnology, labs under Department of Science and Technology and startup support through Biotechnology Industry Research Assistance Council, Atal Innovation Mission, and the e-platform Startup India is driving innovation in healthcare solutions.

Health Technical Assessment brings innovation to implementation, improving public health outcomes and expanding the access to healthcare. Population-scale solutions based on open-source digital resources of Digital Public Goods and Digital Public Infrastructures are redefining the future of healthcare in India.

Ayushman Bharat Digital Mission (ABDM)

- ABDM seeks to establish a digital health ecosystem that offers easy access to medical services. To improve health management, it gives individuals unique health IDs, which enable them to save and manage their medical records online. Nearly 740 million health IDs were generated as of early February 2025[50].
- The United Health Interface (UHI) is an open platform that aims to onboard all parts of a healthcare chain, from doctors, hospitals and blood banks to diagnostic services and laboratories. The single platform can provide a host of services, improving accessibility and efficiency in healthcare delivery. At the end of 2024, over 1,50,000 healthcare facilities were using an ABDM enabled software.[51] Mobile applications have also been introduced.

Ayushman Bharat Pradhan Mantri Jan Arogya Yojana (PM-JAY)

With more than 100 million families enrolled, PM-JAY is one of the biggest health insurance programs globally. It offers health insurance coverage of up to INR5 lakh per family annually for secondary and tertiary care hospitalization.[52] Health and Wellness Centres provide primary healthcare services, including curative, preventive, and promotional care. The eSanjeevani National Telemedicine Service facilitates remote consultations, enabling healthcare accessible in remote areas as well.

Ayushman Bharat Health Infrastructure Mission (ABHIM)

- ABHIM seeks to improve the nation's healthcare infrastructure by setting up building-less public health clinics called Ayushman Arogya Mandir (AAMs). Emphasis is on investing in medical technology and equipment. Its Integrated Health Information Platform (IHIP) is an IT-enabled disease surveillance system linking public health laboratories and facilities across the country.

National Health Mission 2020 (NHM, NUHM)

- With a special emphasis on vulnerable populations, the NHM seeks to offer rural residents high-quality, reasonably priced healthcare.
- Its focus on improving mother and child health outcomes has brought down mortality rates of infants, mothers and neonatal. Installation of sick newborn care units, antenatal, neonatal and child health systems, and logistics tracking tool (ANCHAL) have played a major role.[53]

National Tele Mental Health Programme (NTMHP)

- NTMHP focuses on enhancing mental health services across the country. As of 2025, 53 Tele MANAS cells have been set up, offering services in 20 languages.[54]

New technologies in healthcare and applications

Cloud-based data, delivery systems, AI-supported diagnostics, personalized treatment, improved patient safety and outcomes are some of the areas where healthcare providers are focusing. Process innovations and data-based breakthroughs within the context of technology dvancements like centralized contact centers, enterprise resource planning (ERP), customer relationship management (CRM), health information systems (HIS), and picture archiving and communication systems (PACS) are already being implemented.

Private hospitals and healthcare providers in India are implementing the National Digital Health Blueprint (NDHB) with the help of these platforms to organize and scale operations under centralized supervision. To enable uniform connection throughout the ecosystem, this design offers a unified architecture with layered digital building pieces, such as Electronic Health Records (EHR), Unique Health ID (UHID), and several access channels like contact centers and the Digital Health India portal.

Meanwhile, the growth of hospital-at-home initiatives and remote patient monitoring is transforming patient care by enabling medical teams to treat patients outside of conventional hospital settings. This change is important since it improves the patient experience while lowering readmission rates and relieving strain on the hospital's infrastructure. By facilitating smooth communication between several systems and devices, medical device integration and interoperability advancements are improving clinical efficiency and successfully dismantling data silos in critical care settings.

Robotics and automation

The technology is making significant strides in surgery and hospital workflows, augmenting clinicians' capabilities to improve precision, reduce recovery times, and address workforce shortages

5G-enabled medical devices

The advent of 5G-enabled medical devices promises ultra-low latency and high bandwidth, facilitating applications such as remote robotic surgery and wearable health monitors.

Precision medicine

Precision medicine s set to replace traditional one-size-fits-all approaches, leveraging genomics, lifestyle, and environmental data for highly individualized diagnostics and treatments.

AI-driven solutions for efficiency and accessibility

With the fast- expanding AI market in healthcare, the Indian AI healthcare industry is projected to reach US$1.6 billion (CAGR of 40.6%) by 2025.[55]

Ambient and intelligent care: Ambient AI, human-centered and characterized by context awareness, natural interactions and proactive assistance, is present in healthcare as virtual caregivers available in clinics, homes, or hospitals. It can monitor patients' health and communicate with medical professionals while offering real-time assistance. Inpatient hospital care includes ambient sensors at ICUs, infection control, surgical training, and preventing data fatigue among clinicians by augmenting workflow support. Outpatient clinics can use conversational AI application, combining the virtual assistant functionality with ambient voice detection to automate and speed up documenting into the electronic health record (EHR) and data retrieval for patients' clinic appointments. In home health, fall detection, home rehabilitation, and everyday activity monitoring are

other facets of ambient intelligence. In addition to reminding patients to adhere to treatment programs and medication, virtual assistants can monitor patient health and notify medical professionals of alarming changes.

Agentic AI: While AI enhances workflow automation, real-time decision support and adaptive learning, empowering healthcare professionals to focus on delivering patient care, Agentic AI's autonomous, adaptive and cognitive intelligence evaluates vast amounts of electronic health records (EHRs), test findings, medical imaging and other patient data to spot trends and potential risks. It can derive insights and make proactive treatment suggestions, aiding early disease identification.

AI in public healthcare: The vast potential of AI makes it ideal for application in improving public healthcare. For example, the Clinical Decision Support System (CDSS) in e-Sanjeevni is an AI solution developed by the Ministry of Health and Family Welfare (MoHFW) for diabetic retinopathy identification, abnormal chest X- ray classification and in-progress solutions. Media Disease Surveillance (MDS) is also an AI-powered platform that supports real-time surveillance for infectious diseases. To provide focused information for prompt action and response, this application searches digital news sources nationwide. Up till now, it has released more than 4,500 event warnings since April 2022, helping detect and mitigate disease epidemics[56].

India's BioEconomy: Driving digital innovations

The almost US$166 billion BioEconomy in India[57] is a hotbed of innovation. Bio-IT and Bioinformatics are fast-growing segments that converge the strengths of AI, big data and biotechnology in genomics, bioinformatics, digital biology and health data management.

India is also making strides in genome sequencing, which is crucial for treating genetic disorders, developing mRNA-based vaccines and protein manufacturing. It will enable effective healthcare interventions for specific groups.

Digital twins in healthcare shows promise as virtual replicas of individual patients, allowing simulation, prediction, personalized treatment, enhanced diagnosis, surgical planning, and preventive care.

Virtual reality in remote surgery

With virtual reality (VR), 3D reconstruction of patient anatomy improves precision in surgeries. It enables remote surgeries facilitated by virtual assistants and remote collaborations. Addressing challenges of ethical and legal concerns, high cost, limited accessibility, technical infrastructure and skill development can unleash wider usage.

Quantum computing for medical breakthroughs

Quantum computing, an evolving technology, is expected to play a larger role in MedTech and pharma, processing vast, complicated datasets more effectively than traditional computers. Real-world implementations have started in clinical trials, drug discovery and personalized medicine research. It holds potential in fields like customized medicine, medical imaging, and genomics. Quantum algorithms can improve treatment regimens based on individual genetic profiles, speeding up detection of genetic markers linked to diseases.

The National Quantum Mission (NQM) is the Indian government's initiative to advance the country in quantum technology research and development.

Startups leading the charge in agility and personalization

Startups are fundamentally changing the possibilities of healthcare delivery in India. Some of the segments where the most significant innovation is taking place among startups are:

1. E-pharmacies
2. SaaS-based platform for healthcare providers to offer teleconsultations and telemedicine
3. Digital health interventions for chronic diseases and wellness
4. Minimally invasive surgeries
5. AI-based early detection of some types of cancer out
6. AI-powered radiology diagnostics, Cloud-based remote access to scans and AI reports for radiology
7. Medical equipment procurement and supply chain solutions for tier 2 and 3 hospitals
8. AI to detect insurance fraud
9. Corporate health insurance and employee wellness services
10. Health and fitness platforms providing digital and physical healthcare services, including nutrition guidance and primary care
11. Digital health and wellness platforms offering personalized nutrition plans, fitness coaching, and AI-powered healthcare tools

Recognizing the innovative strengths of startups, institutional support is expanding through public, private and collaborative initiatives. Startup India Seed Fund Scheme and Biotechnology Ignition Grant (BIG; by Biotechnology Industry Research Assistance Council or BIRAC) support biotech and healthcare startups. The BIRAC-India Health Fund focuses on infectious diseases and digital health along with providing incubation facilities and regulatory support.

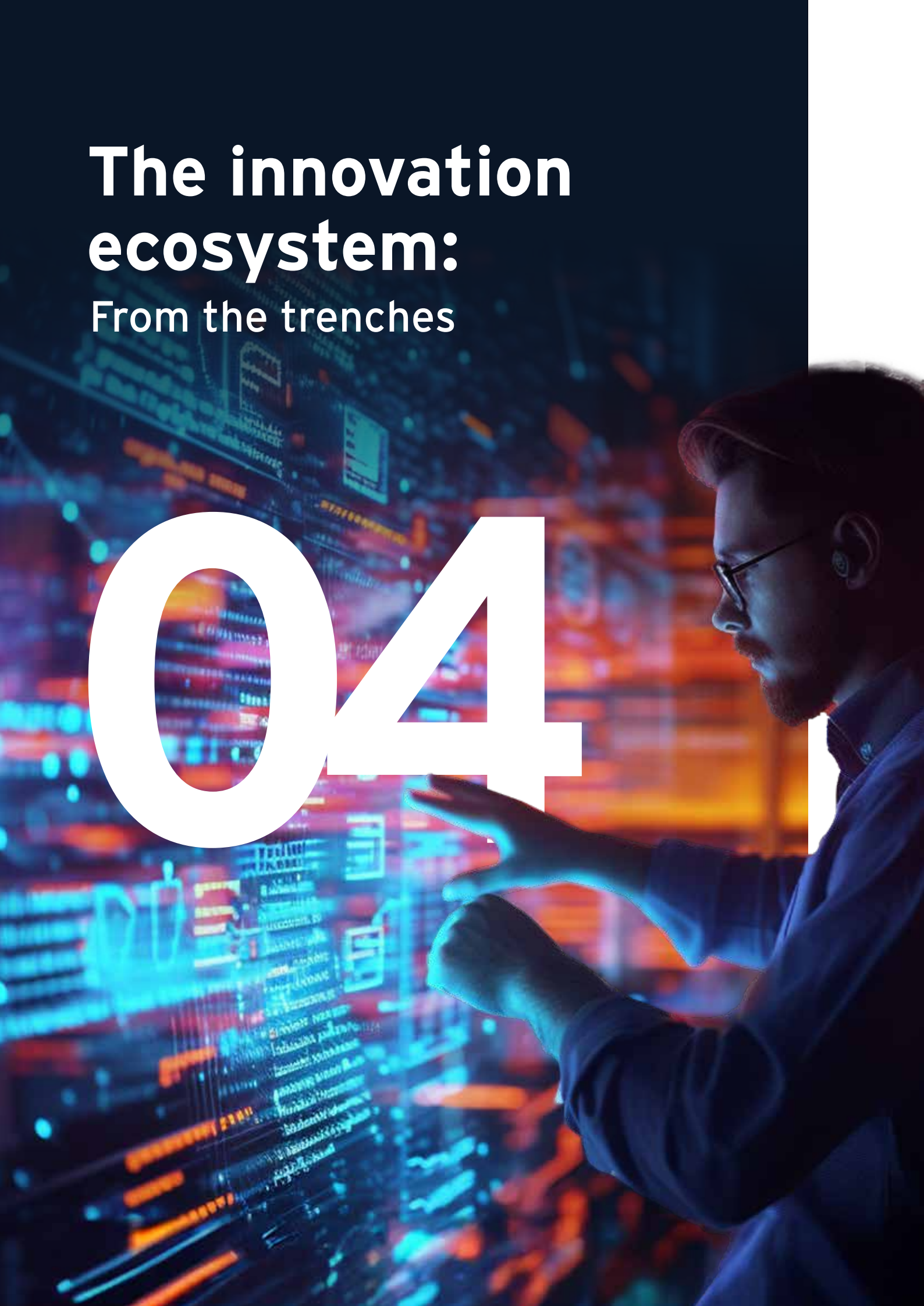
The government has also raised the investment limits for MSMEs, which includes healthcare startups, and launched a new credit card program that extends credit limits to 500,000 disadvantaged first-time female entrepreneur[58].

For startups to widen scope of work and move up the value chain, certain challenges must be addressed. Innovation in healthcare has a long gestation period and can require heavy investments, which can be deterrents as many investors have shorter horizons. Early-stage healthcare startups may struggle as they are not established names with proven models. Scaling across India also requires substantial investments in technology and infrastructure. Regulations on medical devices and data privacy are also challenges. Keeping pace with fast-evolving advancements in AI, specialized hardware configurations, access to high-quality and large datasets can be hurdles for innovation in AI.

The innovation ecosystem:

From the trenches

04

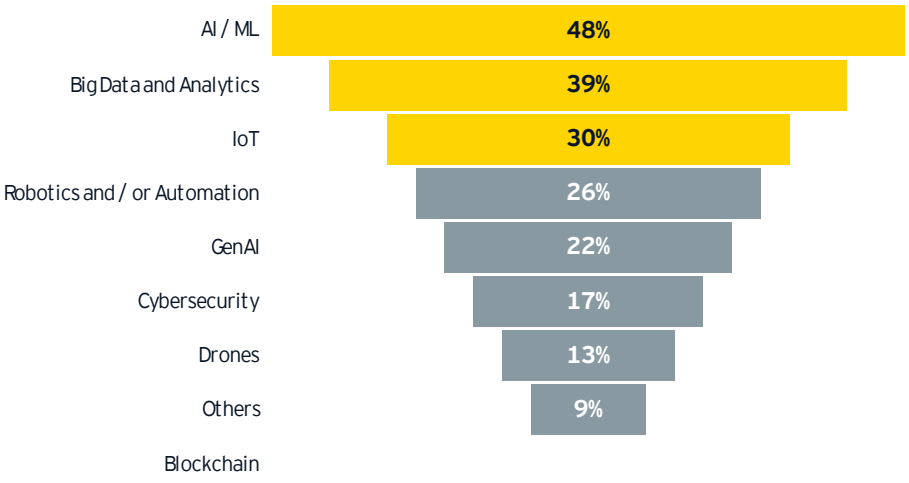


CHAPTER 04

Industry leaders feel innovation in different sectors and enterprises will depend on adoption of AI, ML, Big Data, and IoT. However, challenges persist in funding shortages, change management and skilled workforce. Collaboration among ecosystem players can boost innovation and product development, though government incentives are needed to create policy push in innovation and skill enhancement.

AI/ML, Big Data and Analytics and IoT form the top three high-impact technologies. GenAI has just started making an impact on critical sectors.

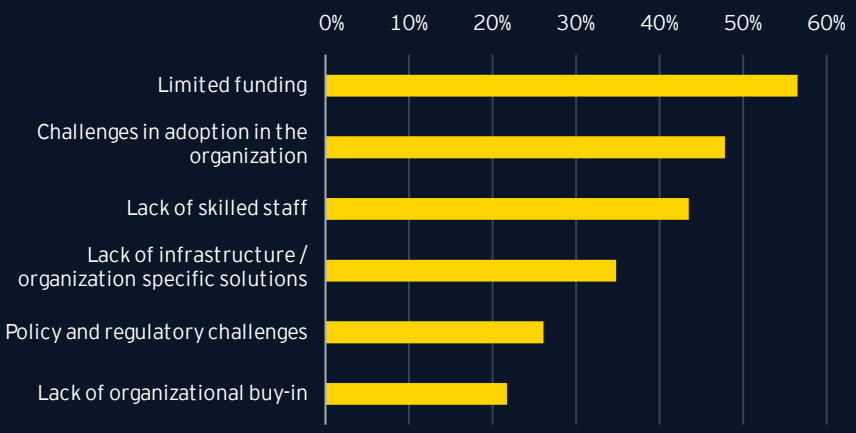
Which technologies have created maximum impact?



Articulation of value leading to lack of funding, change management for new ways of working and having skilled / retrained workforce is holding back digital transformation.

Challenges in adoption in the organization is the highest in the industry whereas funding is the barrier in government and startups. Lack of skilled staff is a consistent second place as an impediment to digital adoption.

Challenges in implementing Digital Transformation



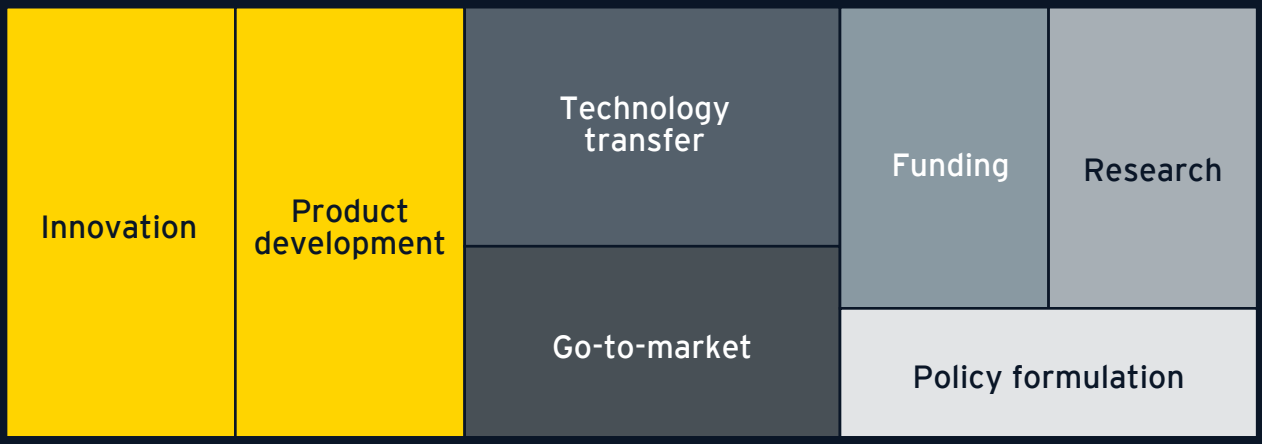
Funding | Adoption

Funding | Skilled Staff

Adoption | Skilled Staff

Funding | Infra

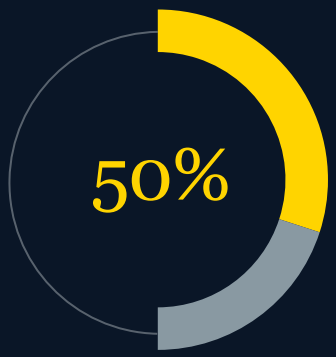
Innovation ecosystem players collaborate with each other predominantly for innovation and product development.



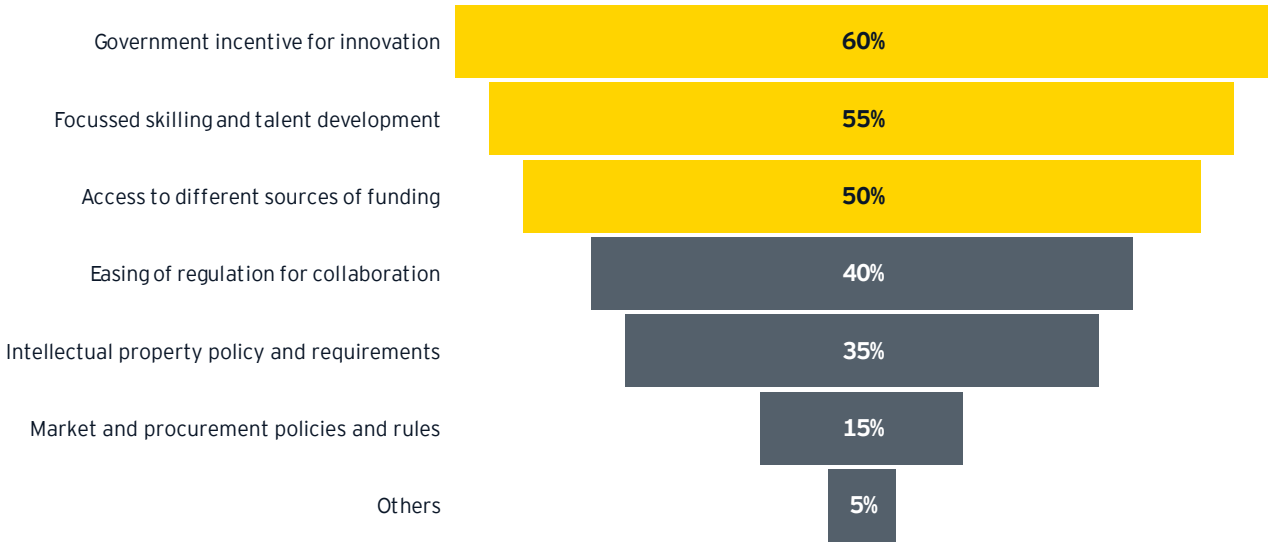
Only

50%

of the respondents are satisfied with the collaboration with the ecosystem.



Ecosystem players are looking for government incentives and schemes for innovation. The focus on skilling is highlighted as the key enabler. This has been highlighted as the key barrier to digital adoption. This is followed by a need for funding for innovation.



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