India @2047: Transforming India into a Tech-Driven Economy

A strategic technology roadmap to achieve India's "Viksit Bharat" ambition

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FOREWORD

India stands at a crucial turning point. With its vast potential, it is poised to emerge as a developed economy by 2047. This report outlines a strategic roadmap to achieve this goal. Based on insights powered by data and vast experience, it illustrates how India can potentially transform into a high-income country with a projected GDP of $23–$35 trillion, utilizing its demographic dividend, technological innovation, and sectoral transformations.

Realizing this potential requires sustained annual growth of 8%–10% and supported by sectoral transformation, technological advancements, and workforce readiness; India may need to undergo a fundamental transition, from a net importer to a globally competitive, export-driven, robust economy. This report identifies five key sectors—electronics, energy, chemicals, automotive, and services—as vital growth drivers, due to their alignment with global trends and scalability. They have the potential to tackle India's unique challenges and accelerate overall economic growth.

Nevertheless, this journey also carries challenges. Infrastructure deficits should be addressed alongside bridging the urban-rural digital divide that impacts rural households, with nearly 70% of the required urban infrastructure yet to be built. Additionally, India would require an estimated overall investment of around $3 trillion to meet its climate goals, including the goal of net-zero emissions. To tackle such roadblocks, India may prioritize work on forging and building international relationships, increasing investments in R&D, and adopting advanced technologies such as artificial intelligence, quantum computing and green energy.

This report aims to achieve a vision which is also an appeal to policymakers, industry leaders, and citizens to collaborate towards a shared future of growth, sustainability, and inclusivity. This document acts as a guiding beacon, illuminating the path to a "Viksit Bharat" where innovation, resilience, and inclusivity intersect to take India to its just position on the global stage by 2047.

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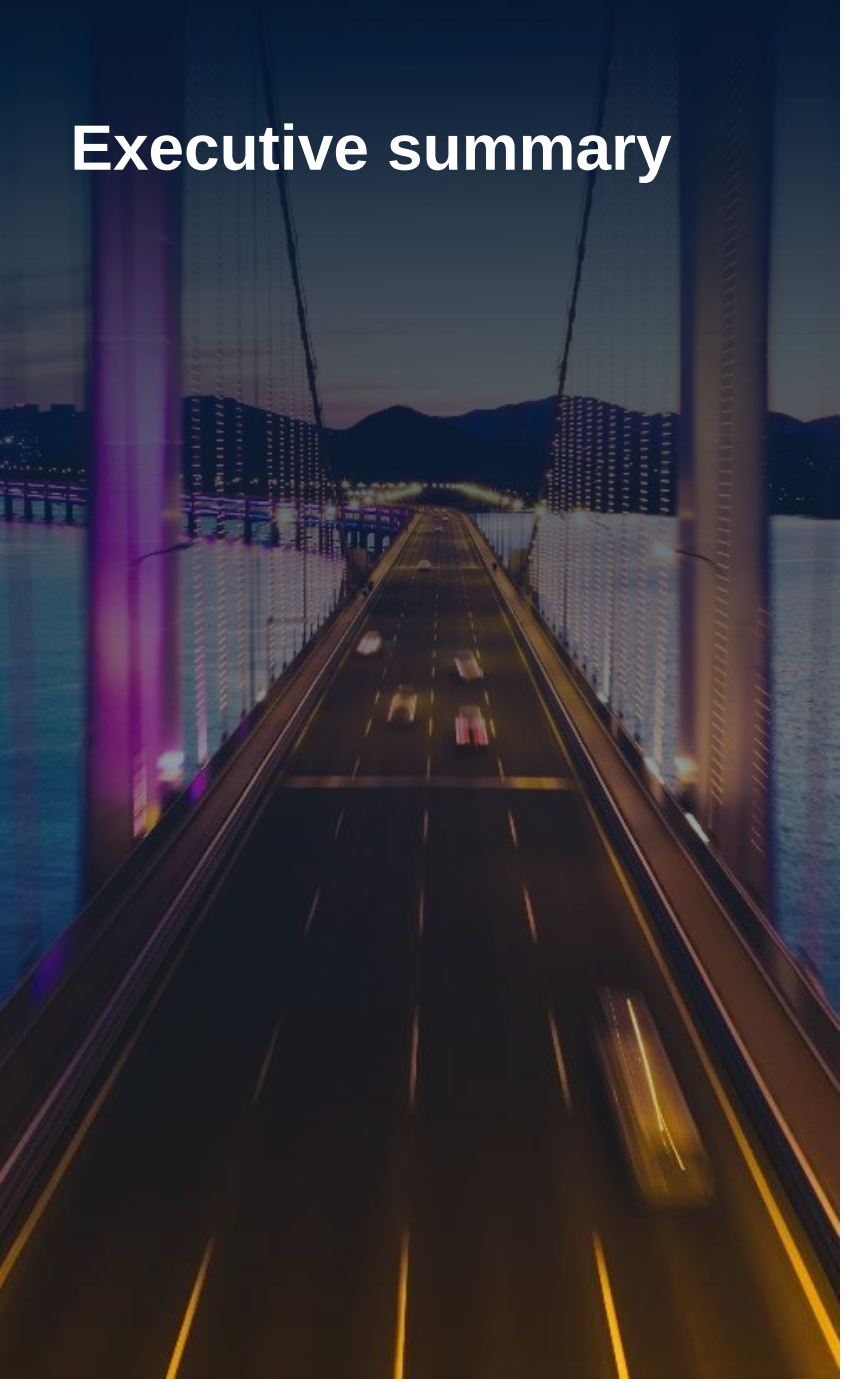


Executive summary

This report outlines a technology roadmap to position India as a high-income, developed economy by 2047 with a projected GDP of about $23–$35 trillion.
Achieving this vision requires sustained annual growth of 8%–10% and depends on sectoral transformations, technological advancements, and workforce readiness. India will potentially need to make a critical shift, transitioning from a net importer to a globally competitive, export-driven economy, particularly in high-impact sectors such as electronics, chemicals, and energy. Establishing India as a global technology leader through advancements in AI, quantum technology, and digital manufacturing could also be pivotal.

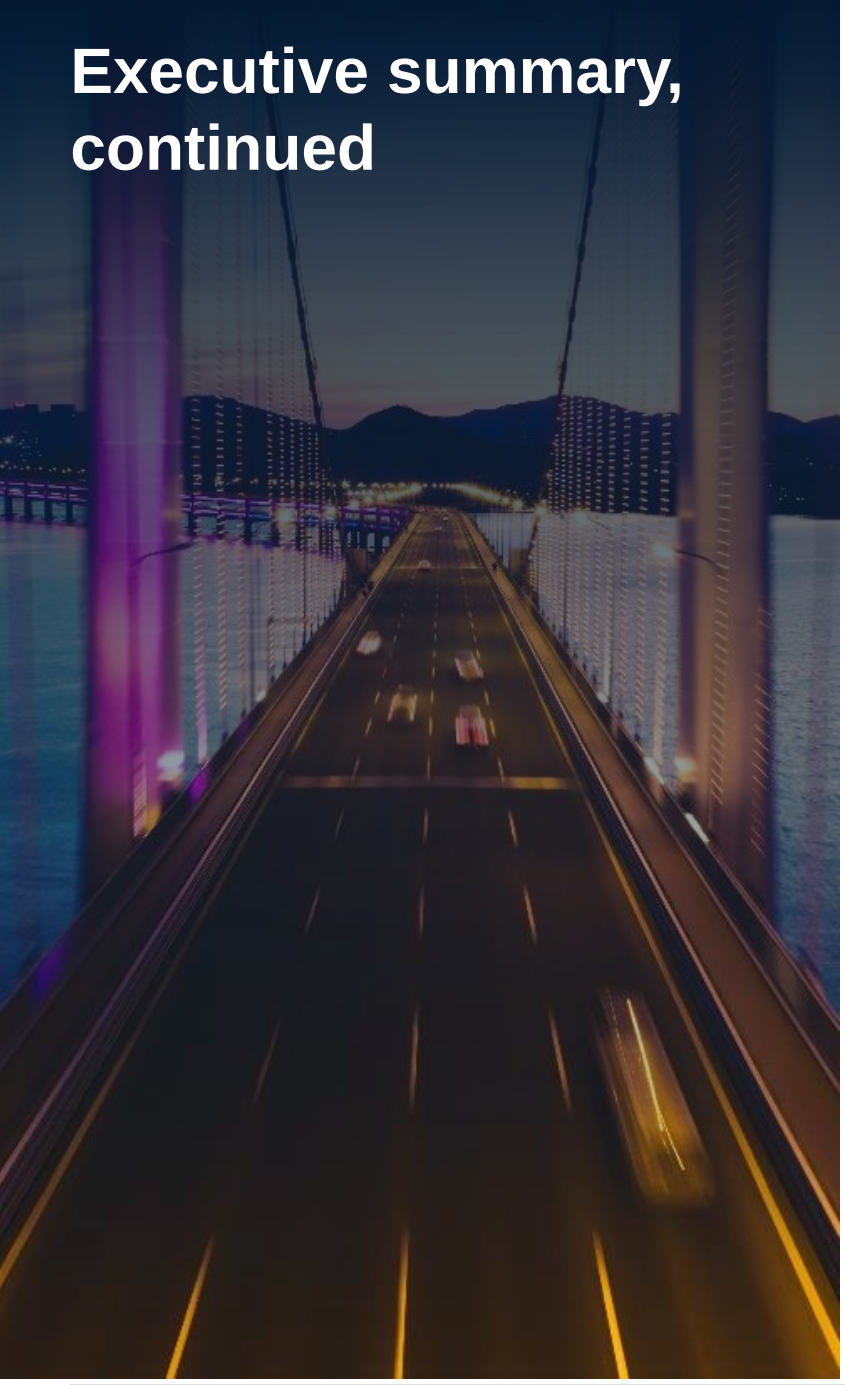
India's demographic dividend could play a crucial role, with about 200 million individuals expected to join the workforce. High-value job creation and increasing female labor participation to 40%–50% could be essential in achieving the 2047 ambition.

This report identifies five key sectors—electronics, energy, chemicals, automotive, and services—as strategic growth levers due to alignment with global trends and scalability. They have potential to address India's unique challenges and advantages. By 2047, these sectors could potentially contribute significantly to the economy. Services are expected to account for about 60% of GDP; manufacturing advancements could enable positioning India as a global hub.

A focused technology roadmap could be key to enabling this transformation:

- **Electronics:** AI-enabled chip design, touchless manufacturing, and biodegradable components could boost productivity and reduce electronic waste. These advancements could potentially expand domestic production, reduce import dependency, and create about 20 million jobs, positioning India as a global leader with around 25% share in electronics manufacturing.
- **Energy:** Smart grids could help optimize energy distribution, while decentralized systems like microgrids could enhance accessibility. Green hydrogen and advanced nuclear technologies could potentially drive carbon-neutral processes, diversify energy sources, and position India as a renewable energy leader.
- **Chemicals:** AI-driven molecular design and digital twins will help enhance R&D efficiency and accelerate innovation. Bio-based production and green practices could potentially enhance sustainability and export competitiveness, targeting around a 10% share in global value chains, particularly in specialty chemicals.
- **Automotive:** Electrification is likely to be propelled by advanced electric vehicle (EV) batteries, connected software, and autonomous technologies. Investments in EV manufacturing clusters and vehicle-to-everything (V2X) communication will potentially establish India as a global hub for smart mobility solutions.
- **Services:** AI, blockchain, and the Internet of Things (IoT) could transform industries like banking, healthcare, and retail. Cloud computing and generative AI could potentially bolster India's IT ecosystem, while high-value service clusters in Tier 2 and Tier 3 cities could potentially foster inclusivity and global leadership in digital transformation.

Executive summary, continued



India’s transformation is not without challenges. Infrastructure deficits in transportation and the urban-rural digital divide require extensive investment. A projected workforce skill gap of about 50 million people by 2030 potentially necessitates expanded STEM education and targeted skilling initiatives. Reliance on imports for critical components underscores the importance of focus areas like backward integration and local manufacturing, while climate commitments demand transition to a green economy.

Addressing these challenges requires a tech-enabled, multi-pronged approach involving domestic and international efforts.

- **Domestically:** Public-private collaboration may accelerate innovation in critical sectors like AI and green energy. Increasing R&D investment as a percentage of GDP could potentially foster domestic innovation and reduce India’s dependence on global supply chains. Workforce inclusivity, particularly gender equity, can likely be boosted with tech interventions to unlock untapped economic potential and support sustainable growth.
- **Internationally:** Strengthening India’s position in global value chains through Free Trade Agreements (FTAs) and export diversification into emerging markets like Africa and Latin America could potentially reduce reliance on traditional trade partners. Collaborative R&D in areas such as quantum technology and advanced materials may bolster India’s technological edge.

By aligning sectoral growth with sustainability and inclusivity, India can realize its vision of an approximately $23–$35 trillion economy by 2047. This transformation could potentially elevate India’s global standing, improve the quality of life for residents, and establish the nation as a leader across economic, technological, and social dimensions.

GDP vision for 2047

India's "Viksit Bharat" ambition to develop into a fully developed economy by 2047 requires a focused technology roadmap

Ambition

GDP OF $23–$35T
3RD LARGEST GLOBAL ECONOMY
HIGH-INCOME NATION WITH PER CAPITA INCOME (PCI) OF $15–$20k

Key markers

Global industry leaders	Diverse workforce	Cutting-edge infrastructure	Self-sufficient production	Sustainability champion	Technology leader
10 Indian firms in top 100 globally; 3–4 champions across sectors	**50%** female labor force participation	**Tech & non-tech infrastructure** across rural and urban areas	**Export-led** economy across major sectors	**Large renewable capacity,** with low greenhouse gas (GHG) emissions	**High R&D and innovation,** across emerging technologies

Key enablers

Global competitiveness via technology
Developing robust ecosystem for innovation and technological advancement to bolster India as a leader in emerging global industries

Greater skilled labor force participation
Tech-enabled upskilling and reskilling could improve productivity and skill level of Indian workforce and promote greater inclusivity

Advanced manufacturing capabilities
Possible reduction of reliance on foreign nations via adoption of tech and modernization of manufacturing processes

Sustainable infrastructure
Development of sustainable and inclusive infrastructure that potentially ensures equitable access to resources

India could target key evolving sectors, accelerating technology, and productivity levers to achieve its GDP goals for 2047

1. Envision India as a $23–$35 trillion developed economy by 2047, requiring a sustained growth rate of 8%–10%, which needs **acceleration on multiple fronts**

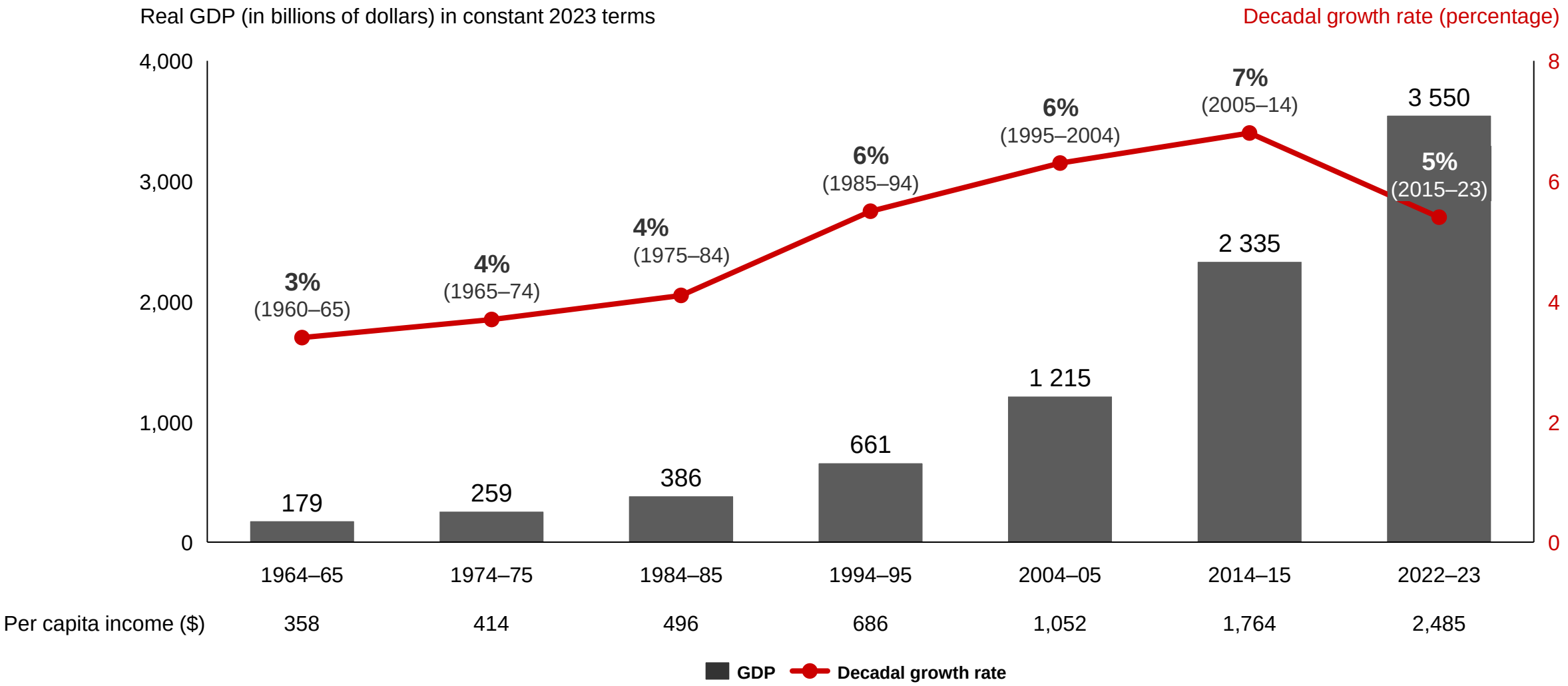
2. Progress along the growth journey by balancing the dual objectives of **GDP growth and employment creation** for the next approximately 200 million entering the workforce by 2047; harness the opportunity of the next 25 years to possibly leverage the **demographic dividend** led by a favorable dependency ratio and growing labor force

3. **Drive transformational growth through sectoral shifts**, as seen in the evolution of other economies on similar paths; services and manufacturing could disproportionately drive India's growth, growing at about 10%, while agriculture is expected to see a modest growth at about 6%

4. Drive 1.5%–2% of growth through labor quantity and quality; concentrate infra-focused capital spending to encourage another approximately 5% of growth; invest in **technology and communication infrastructure, technology-led TFP** increase with modernization across industries, structural reforms driving tech sophistication—supplementing the remaining 2%–3% required which could potentially achieve the target GDP growth

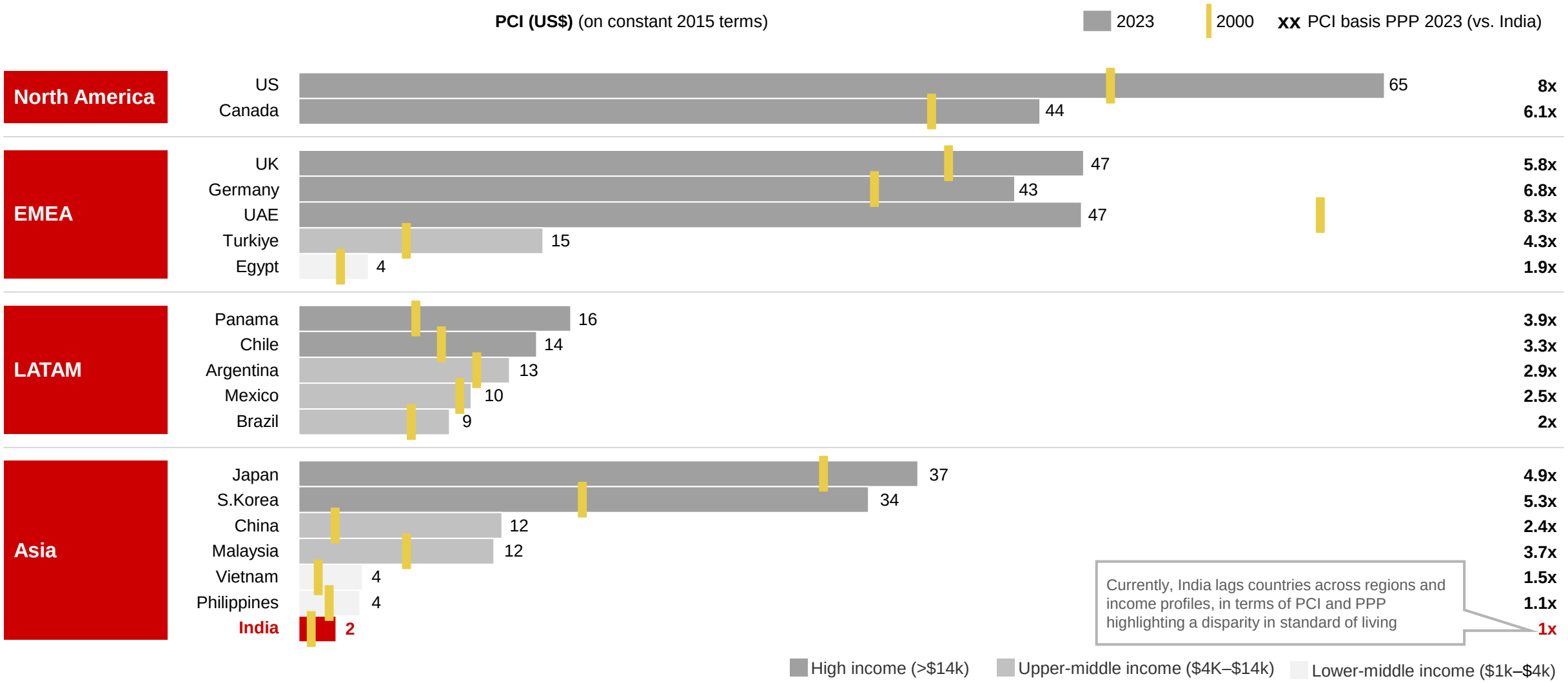
Note: TFP = total factor productivity

India experienced a decade of 5%–7% growth post-liberalization, driving the ① economy to about $3.6 trillion GDP and per capita income to about $2,500 in FY23



Notes: All values in constant 2023 US$ terms; Growth rates for decade ending at given year; 1965 growth rate calculated over five years (1960–65), 2022–23 growth rate from 2015–23
Source: World Bank

Despite recent gains, India has a significant per capita income gap compared to other developing and developed economies



Notes: GDP per capita figures used to represent PCI based on constant US$ prices in 2015; PCI = per capita income; EMEA = Europe, the Middle East, and Africa; LATAM = Latin America; Income cut-off based on World Bank classification PPP = public-private partnerships | Source: World Bank

To become a developed economy and achieve the “Viksit Bharat” ambition by 2047, ① India must sustain 8%–10% growth annually

GDP $ (2023[1])
3.6T

PCI $ (2023[1])
~2.5k

Scenarios for India’s growth journey until 2047			Countries emulating similar growth in their boom period			
GDP CAGR[2] (2023–47)	**Real GDP $** (2047)	**PCI $** (2047)	**Number of countries[3]**	**Illustrative**		
10%	35T	20.8k	5–7	**China** 10.1% (1980–2010)	**South Korea** 9.8% (1965–95)	**Singapore** 9.3% (1965–85)
9%	28T	16.7k		**Qatar** 11.1% (1995–2015)	**Saudi Arabia** 11.8% (1960–80)	
8%	23T	13.4k	8–10	**Malaysia** 7.5% (1975–95)	**Brazil** 7.4% (1960–80)	**Thailand** 8.0% (1975–95)
				Vietnam 7.1% (1990–2010)	**Japan** 7.0% (1960–80)	
6%	16T	9.6k	~15	**Ireland** 6.0% (1985–2005)	**Chile** 5.9% (1985–2005)	
5%	13T	7.6k	~15	**Türkiye** 5.0% (1995–2015)	**Argentina** 4.0% (1990–2010)	

Select countries have sustained 8%–10% growth in their boom period

Notes: 1. GDP and PCI in 2023 market rate terms; 2. Real growth rates and real GDP considered; 3. Based on sample data from 81 countries contributing about 95% of world GDP in 2023; PCI = per capita income | Sources: CEIC; IMF; Bain analysis

① India is likely to face several challenges in sustaining a high growth rate

Challenges

Escalating geopolitical turbulence

- As the world becomes more **protectionist** with increasing geopolitical tensions, there is a possibility of a **slowdown in capability transfer to emerging economies**—harmful interventions have tripled since 2019, trending toward localized supply chains and "friend shoring"
- Technological fragmentation/decoupling (driving the shift toward developing own tech vs. relying on foreign tech) is estimated to cost up to 5% GDP for middle-income economies

Rising financial constraints

- **Elevated public and private debt levels** across the globe are leading to **monetary tightening and higher borrowing rates** for economies, squeezing government budgets
- This reduces the fiscal space required for capital investments in education, infrastructure, and green transition—India spends more on debt service than on health, education, etc.

Accelerating climate change

- **EMs are more exposed to risks from climate change**—rising volatility in temperature and rainfall affects agriculture, hydro, and thermal power generation and threatens food, water, and energy security in India
- EMs face trade-off between shorter-term macroeconomic goals and long-term climate action plans; both require high upfront investments—climate adaptation would cost about 1% of GDP for middle-income countries

Potential levers

Exploring potential for securing **bilateral agreements** with economics for key sectors, potentially identifying opportunities beyond exports and enhancing **domestic innovation**

Encourage **private investments** for driving capital formation in infrastructure, healthcare

Strive for decarbonization of the Indian economy, by possibly leveraging clear policy targets and incentives for the private sector

Note: EM = Emerging markets (developing economies); Sources: World Development report 2024–World Bank; Bain analysis

① Additionally, several areas require structural reform to boost growth

Key focus areas

Narrow window of demographic dividend

- With rising life expectancy and falling fertility rates, **India has limited time to reap the demographic dividend** to power its growth—estimated to take about 25 years for India to transition from an aging to an aged population (vs. about 61 years for many high-income countries in the past)
- By 2050, 1 in 5 Indians is likely to be a senior citizen

Infrastructure for supporting urbanization

- Share of urban population expected to go up to 51% by 2047 from 35% currently, due to a shift from farm to non-farm employment; about 70% of the urban infrastructure required for 2047 is yet to be built
- There is a high reliance on government funding at present, with more than 70% of required funds provided by central and state government; yet **commercial financing funds only about 5%,** restricting the pace of infrastructure development
- India's present approach to urban infrastructure planning does not align with long-term planning tools—urban local bodies roll out mega projects on an ad hoc basis which may lead to disjointed land use

Inclusive development

- India currently ranks 66 out of 109 countries in Global Multidimensional Poverty Index (MPI), which considers the 3 macro dimensions of health, education, and living standards
- Government has launched several policies in recent years focused on MPI, which can improve health (Poshan Abhiyaan), education (Samagra Shiksha), and living standards (Pradhan Mantri Awas Yojana, Pradhan Mantri Jan Dhan Yojana), potentially progressing on sustainable development goals

Potential levers

Invest in upskilling and employ the next 200M+ population in productive jobs over the next 25 years

Private financing to play a critical role—urban local bodies can invest in capacity building and execution
Need for **systematic land-use planning**, development control regulations, and focus on critical projects

Continued focus on equitable growth—can include policies to improve education, healthcare, and quality of life

Sources: World Bank; Euromonitor; Bain analysis

India is expected to add about 200 million to the labor force by 2047 and needs to ② prioritize employment creation to grow

India's current labor force participation rates (LFPR) and scenarios for 2047

Labor force (in M)	500–550	650–700	700–750	850–900
LFPR	Male: 79%; Female 29%	Male: 80%; Female 40% (Moderate likelihood)	Male: 81%; Female 50% (High likelihood)	Male: 82%; Female 70% (Low likelihood)
Net addition to labor force for India by 2047 vs. 2022	-	**about 150M**	**about 200M**	**about 350M**
Countries with similar LFPR	-	Türkiye	Mexico	China Vietnam

Likely scenarios for India

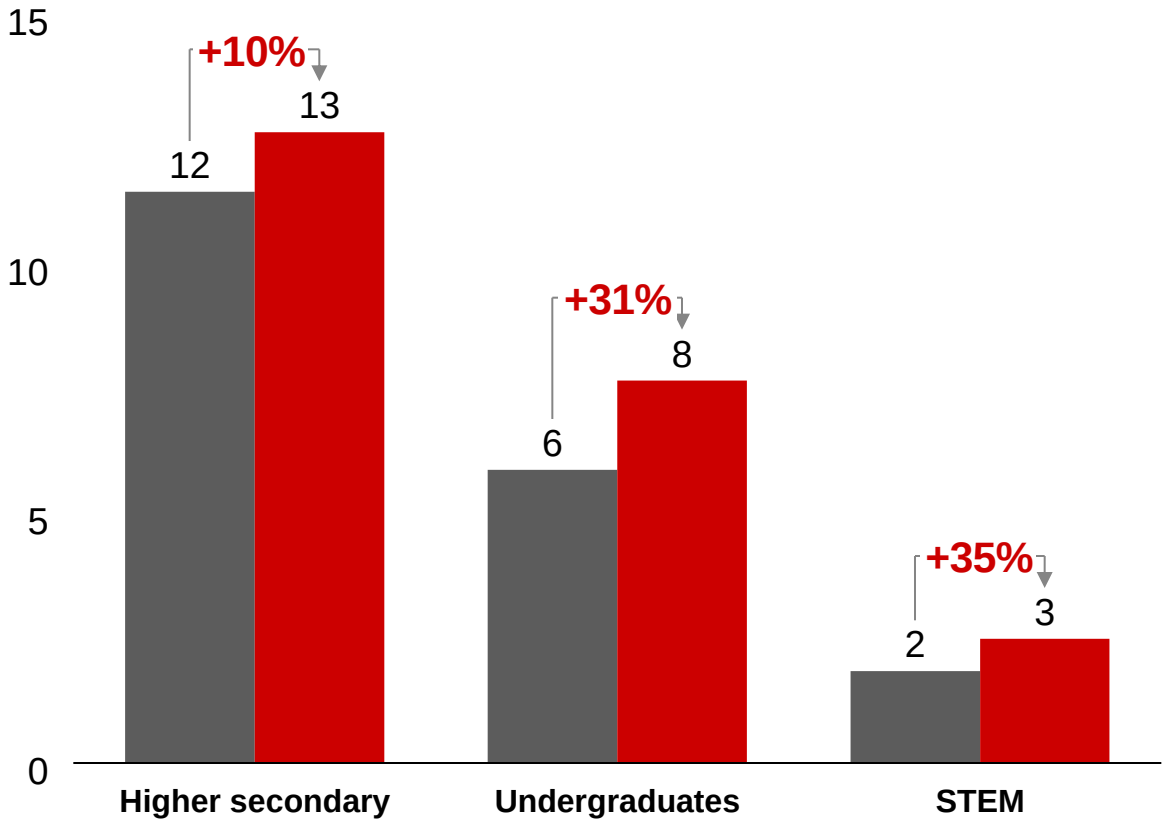
Note: MSME = micro, small, and medium enterprise
Sources: ILO; UN population statistics; Bain analysis

Potential levers

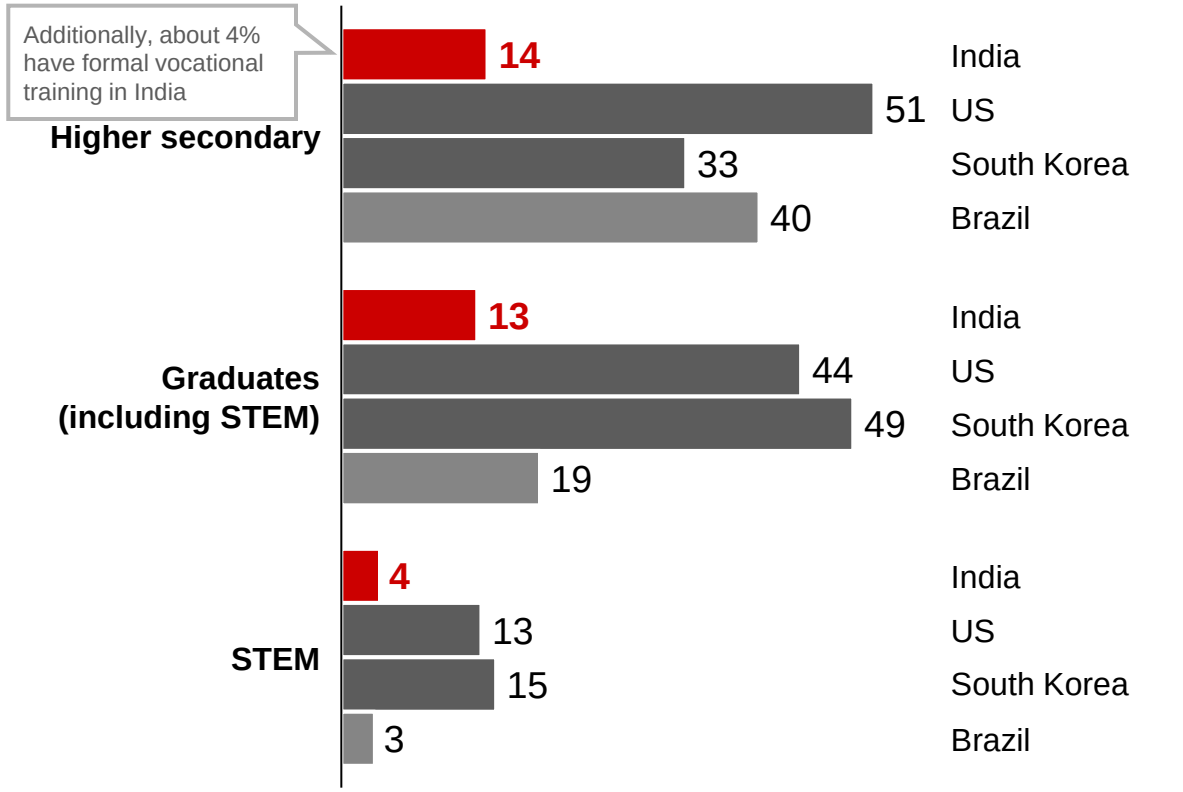
- **Increase female participation**
  - Address issues around education, wage parity, working conditions
  - Build ecologically embedded entrepreneurial ecosystems that can ease transition of women to work
- **Improve the quality of talent**
  - Low employability at present: 65% of population under the age of 35, but only 51% employable
  - Develop digital infrastructure to provide better education access
  - Revamp education curriculum—modernize delivery methods, focus on digital skills, vocational training
- **Create and formalize jobs, solve for demand challenges**
  - Support new businesses via better capital access, ease of doing business (e.g., one-stop compliance portal)
  - Focus on formalization within key industries (e.g., MSME) given more than 80% employees in informal sector

While education and skilling are expanding, there are more opportunities to improve ② the quality of India's workforce

Number of students passed (in millions)

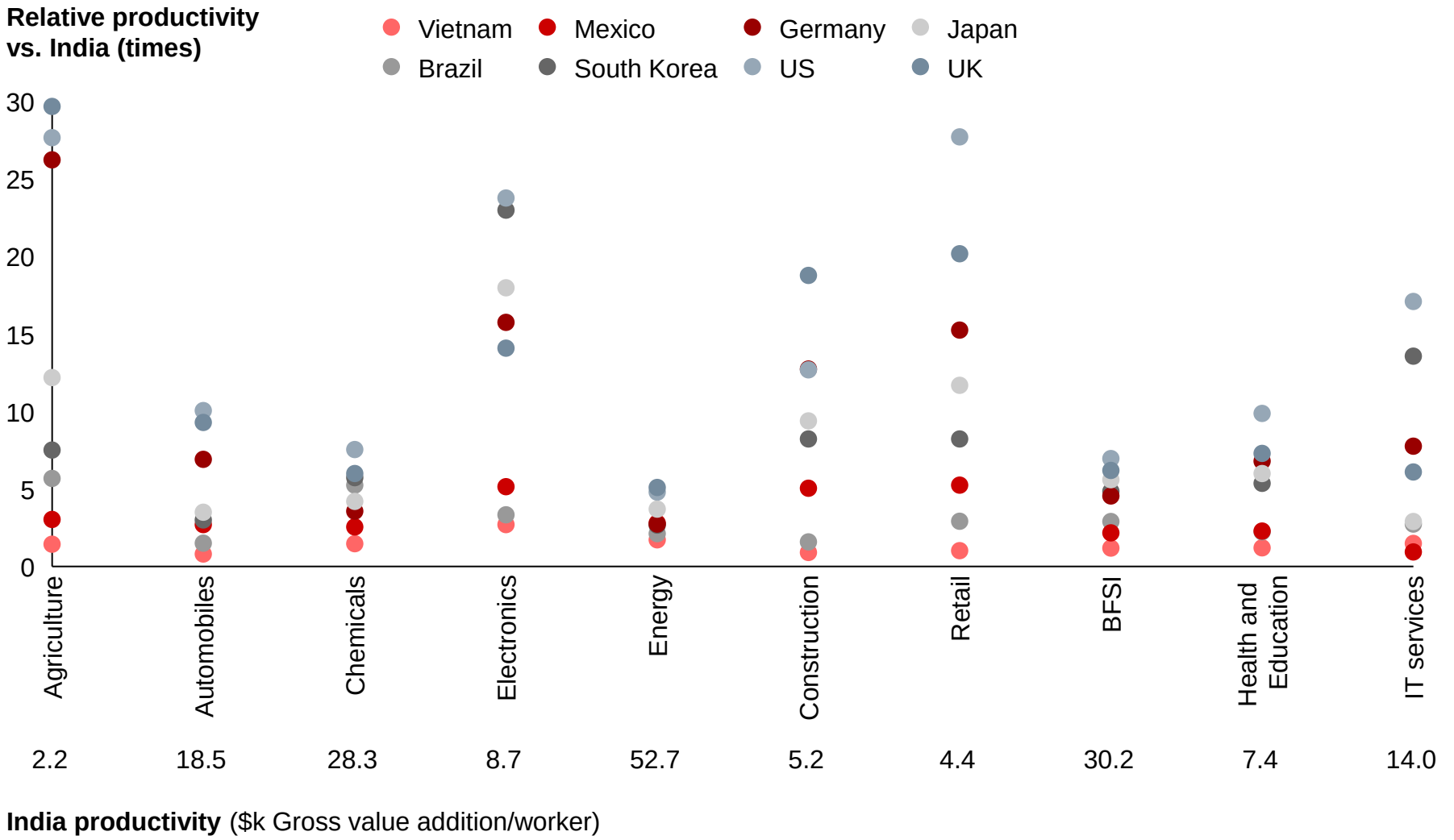


Highest level of education, percentage of working age population across countries with varying income levels (2023)



Note: Ministry of Education—All India Survey on Higher Education; AISHE report; UNESCO Institute of Studies; ILO; PLFS

③ India has a productivity gap with its global peers and should prioritize efforts to boost productivity in high-value-adding sectors



Potential levers

Tech adoption is critical to potentially improve productivity and achieve high-growth ambition

- Encourage automation which can enhance efficiency
- Digitalize traditional sectors

Sectoral shifts to drive higher value-addition

- Globally, service sectors (e.g., energy, IT, BFSI); manufacturing sectors (e.g., chemicals, electronics) contribute the highest to overall productivity
- Encourage shifts to products with higher value-add

Talent supply to bridge productivity gap

- India has started to bridge the productivity gap in IT services, on account of its low-cost talent supply; key to invest in education for a more skilled workforce

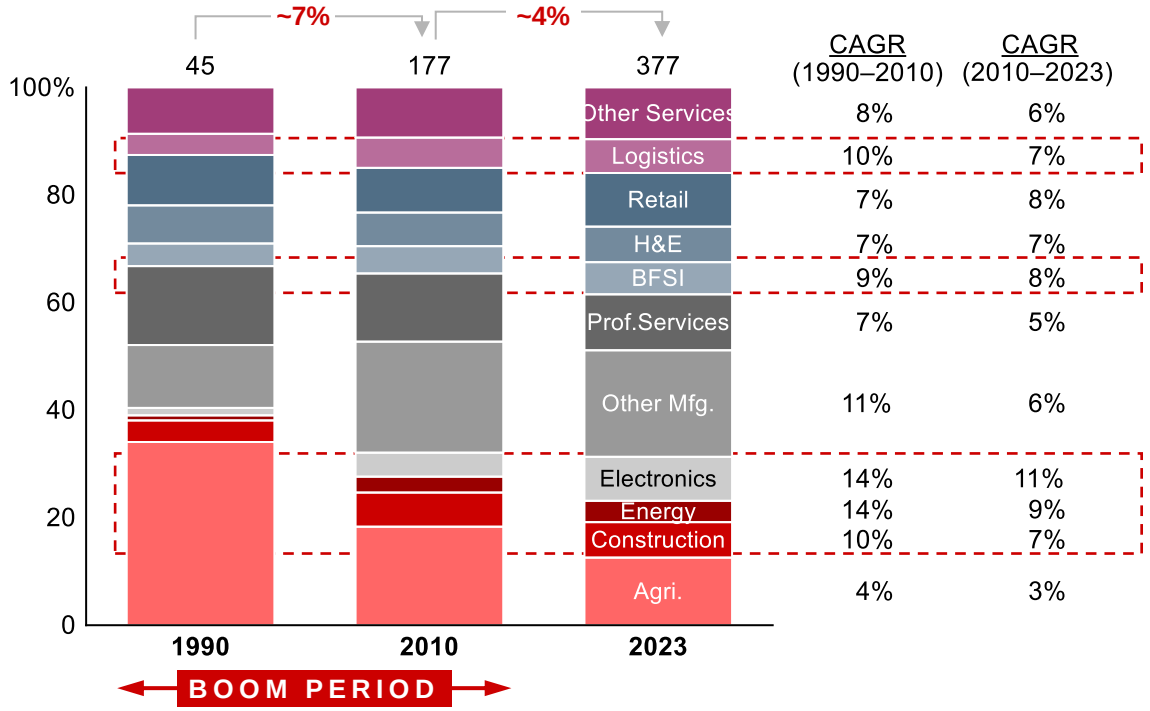
Note: BFSI = banking, financial services, and insurance; Relative productivity calculated as ratio of country productivity to India productivity by sector; Other manufacturing includes food processing, materials, machinery, repair, wood and paper products; Other services includes telecom, utilities, leisure and hospitality; Professional services includes services (e.g., legal, accounting, advisory, public services) | Sources: IHS Markit; World Bank; ILO; Bain analysis

Evolution of GDP contribution by sector during periods of high economic growth/ ③ boom period and recent decade

High-growth segments | ILLUSTRATIVE

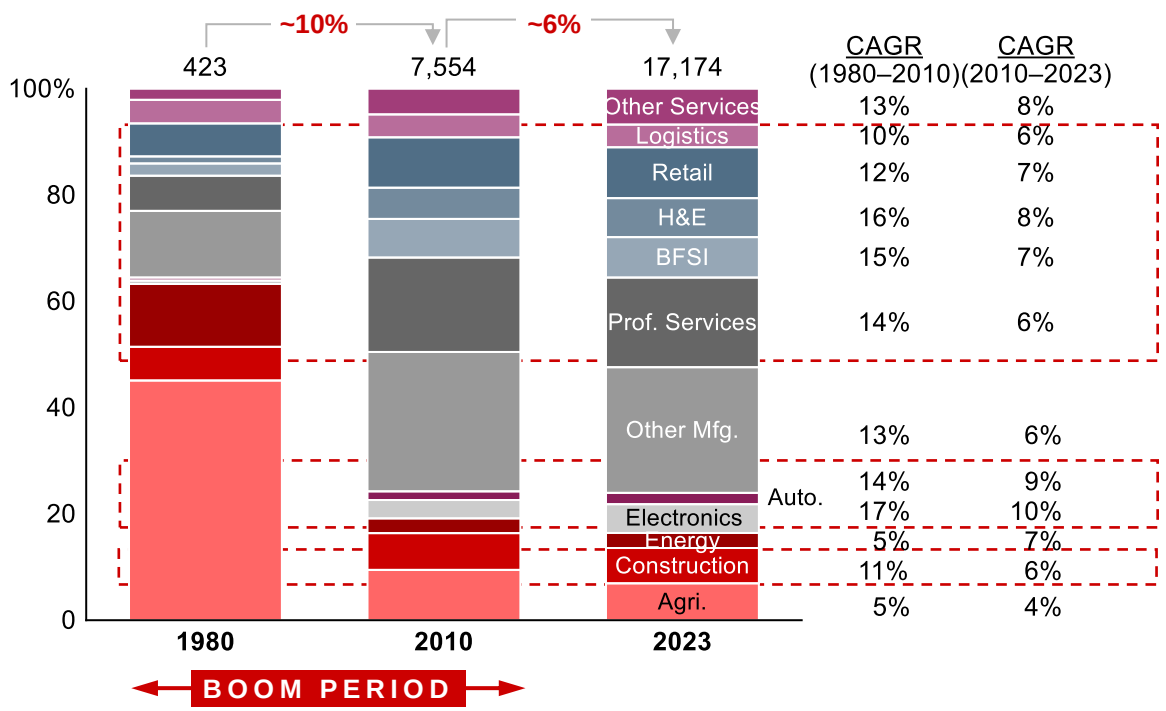
Vietnam (lower-middle income)

Contribution to GDP (in billions of dollars)



China (upper-middle income)

Contribution to GDP (in billions of dollars)



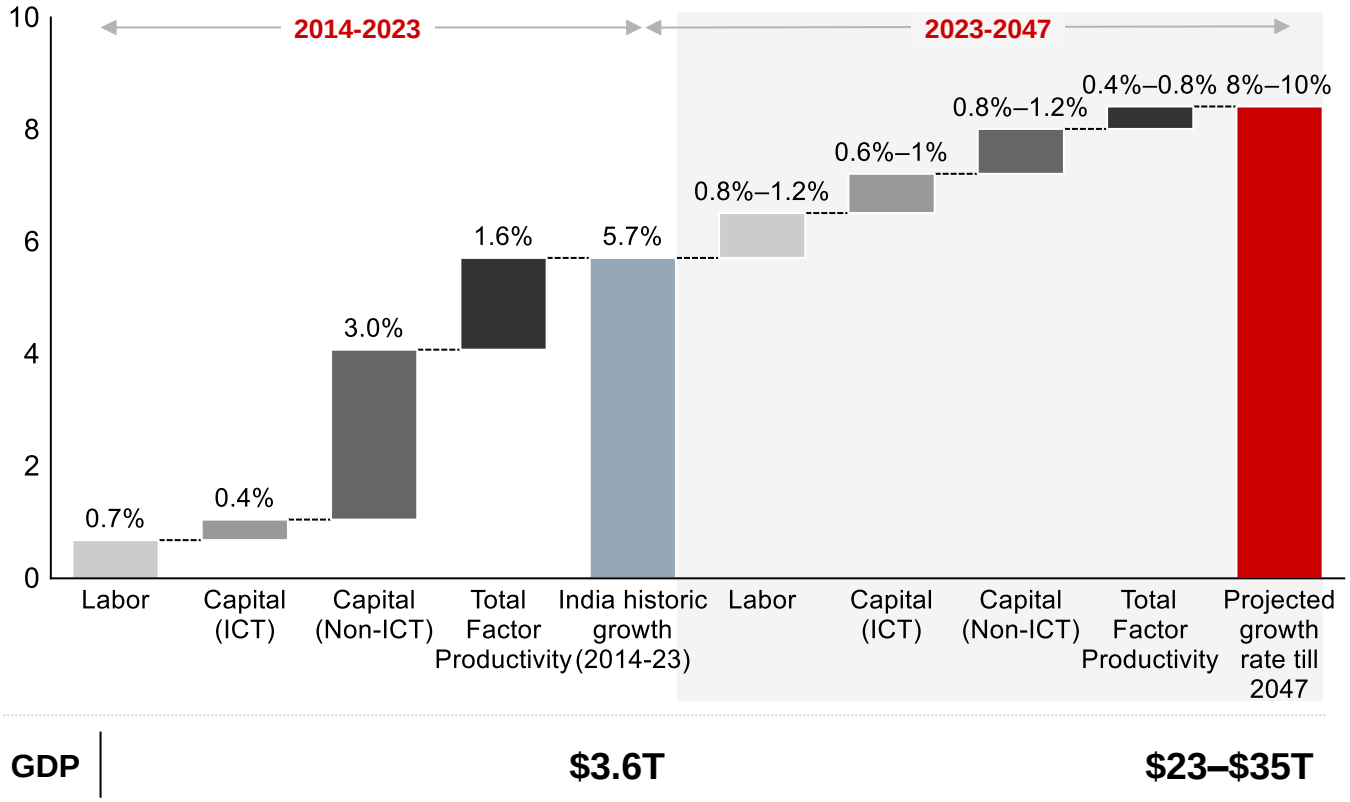
Services (e.g., BFSI, logistics, retail, health, education, and professional services), along with select industrial segments (e.g., construction, energy, and electronics) were drivers of growth during boom period for Vietnam and China

Notes: Other manufacturing includes chemicals, food processing, mining, materials, machinery, repair, wood and paper products, automobiles, textiles; Other services includes telecom, utilities, leisure and hospitality; Professional services includes legal, accounting, advisory, public services; H&E = Health & Education; BFSI = banking, financial services, and insurance; GDP in real terms (constant 2015 US$) | Sources: IHS Markit, Bain analysis

④ Going forward, India can sustain growth through some key focuses (e.g., increasing capital spending, productivity, and workforce participation)

Drivers of GDP growth rate for India: Historic vs. future

Breakup of real GDP growth by factors (%)



Labor: about 1.7pp

- Increasing female labor force participation from about 29% to up to about 50% by 2047
- Upskilling and increasing the number of graduates can lead to an increase in productivity and contribution by labor across sectors

Capital ICT: about 1.2pp

- Spend on telecom capex with multiple telecom rollouts, which can improve the telecom infrastructure
- Proliferation of AI/machine learning (ML), generative AI, rising cloudification, and increased data generation and service usage potentially driving up demand and capacity for data centers by 15%–20% YOY

Capital non-ICT: about 4pp

- Expected infrastructure investments of $11–$15; $6T spending in urban infra for raising Mass Rapid Transport from 750 km in 27 cities to 5k km in 75 cities
- Doubling of railway network to 2L kms, adding 4.5k Vande Bharat trains; Expansion of highway length by 1.6x to 45k km expressways; 4x capacity in ports, aviation—overall investments at $6–$7T

TFP: about 2.2pp

- Measures efficiency of resources in producing output, reflecting gains from technology and innovation (e.g., digital interventions reducing turnaround time at ports)

Notes: GDP growth split into four factors: labor (labor quantity, i.e., size of labor force and quality including skills and qualifications), ICT Capital (Information & Capital Technology assets incl. computer hardware and equipment, telecommunication equipment and computer software and services), Non-ICT Capital (other capital assets incl. such as buildings, transport equipment, and machines), TFP = total factor productivity (captures changes in productivity based on technology, innovations, market reforms, etc.) | Sources: Conference board; Gartner; Bain analysis

To progress toward a high-income economy, India could benefit from an infusion of ④ technologies along with robust capital accumulation, which may drive innovation

Transition	Low income → Lower-middle income	Lower-middle income → Upper-middle income	Upper-middle income → High-income status
Top priority	**Capital accumulation** Facilitate **government and private investments** alongside efforts to enhance domestic consumption, import substitution	**Infusion of global tech** Leverage **modern, global technologies** while strengthening technical capabilities through education and training	**Domestic innovation** Foster **global knowledge creation and innovation** through enabling institutional and regulatory policies
Typical PCI ($)	$1.1–$4.5k (lower-middle income)	$4.5–$14k (upper-middle income)	greater than $14k (high income)
Key metrics to track	Capital accumulation Capex as percentage of GDP Basic labor skilling (gross enrollment ratio)	Scale of govt. incentives (e.g., PLI) STEM talent supply Tech sophistication index (TSI)	Avg. R&D spend percentage of revenue Number of patents per M population Number of researchers per M population
Examples of successful transitions	**Brazil** **Credit fueled investments drove significant growth** • Incentives for import substitution accelerated growth, increased investments fueled by foreign credit in the 1970s • Protectionist policies restricting foreign tech infusion reduced productivity	**Chile** **PCI doubled to $14k (2023) vs. $7.2k (1995) with knowledge transfers from adv. economies** • Imports of foreign products (incentivized by favorable policies) and tech early on encouraged domestic competitiveness • Aided SME tech transfer, capability building through ecosystem support from large cos	**South korea** **PCI growth from $1.2k (1960) to $34k (2023)** • Invested in education to build a strong base of engineering and management workforce • Tax credit, royalty payment for R&D invt. • Pro-entrepreneurship policies, improved financing for domestic ventures, easing of anti-trust regulation to promote competition

India's position today

Notes: PCI = per capita income; PLI = production-linked incentive | Sources: World Bank country classification by income level; Bain analysis

④ Technologies and innovations to grow the economy can take many forms across individuals, businesses, and government

Individual adoption

To improve skilling and education

To improve healthcare to reduce number of sick-days and include productivity

To promote financial inclusion to ease access to capital

To enable women's participation in the workforce

To enable access to public services (e.g., Aadhar, JAM trinity)

To reduce unit cost of delivery, increase individual productivity and access to tech

Business adoption

To enhance overall productivity by adoption of existing tech (e.g., textile value chain automation in low-value, repeatable activities in Bangladesh)

To kickstart growth by strategic and new tech adoption (e.g., digital twin to streamline auto mfg., drones for preventive maintenance of energy assets)

To find additional growth opportunities by venturing into new business models (e.g., software factory of the world)

To increase overall business level productivity and enable tech-led growth

Government adoption

To facilitate democratization of technology by building of Digital India

- Digital public goods like India stack with open standards supporting UPI, ONDC, NHS (healthcare), GeM

To promote domestic innovation by capex infra support including ICT

To enable skilling in key emerging tech and cybersecurity (e.g., programs by MeitY)

To enable access to safe tech and platform for future innovations

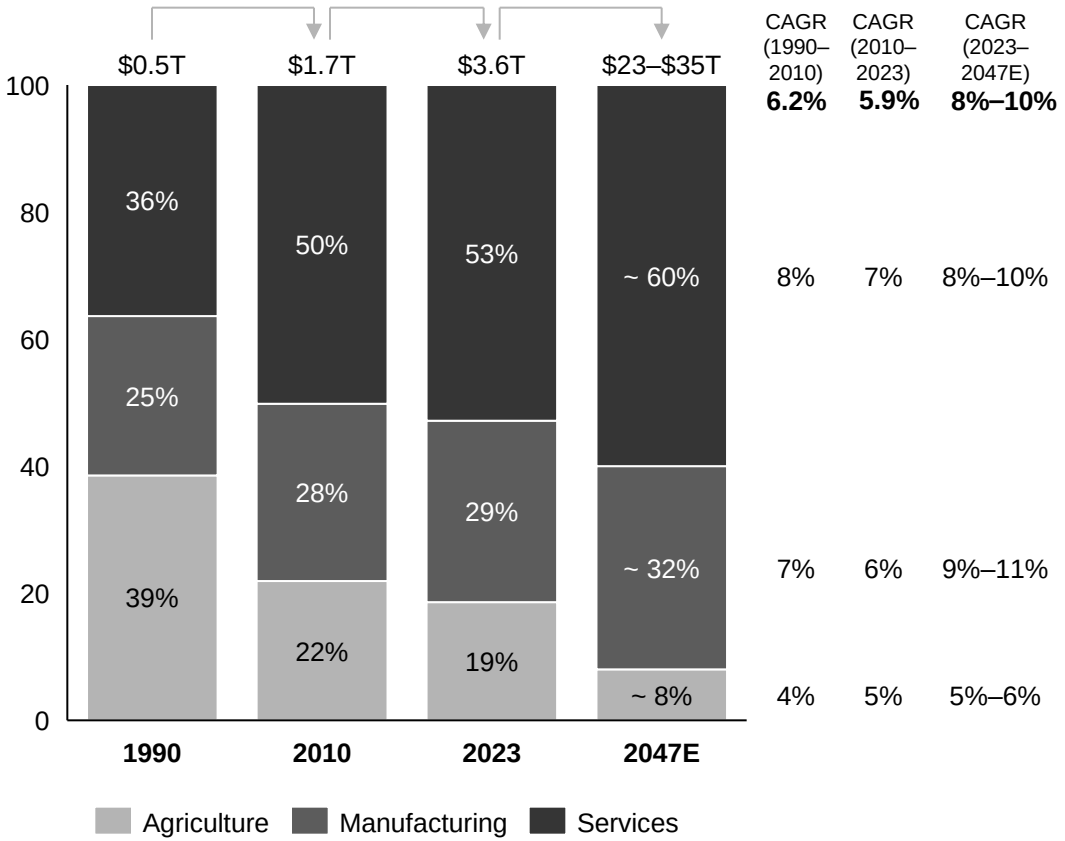
Notes: JAM = Jan Dhan, Aadhar and Mobile; UPI = unified payments interface; ONDC = Open Network for Digital Commerce; GeM = government e-marketplace; ICT = information communication technology

Sectoral deep dives

With rising per capita income, the services sector is expected to be a key driver of GDP growth, with manufacturing also playing a significant role

India's GDP could reach $23–$35 trillion by 2047, supported by strong growth in services and manufacturing

Sector-wise contribution to India GDP (percentage)



Notes: PCI = per capita income; GCC = global capability center
Sources: World Bank; IHS Markit; PHD Chamber of Commerce; secondary research; Bain analysis

Key growth drivers across sectors include rising income, availability of skilled talent, and supporting infrastructure development

Agriculture

- Growth fueled by **rising population, higher consumption, better yields**, and **continued government support**
  - Provision of about $18B for agriculture and allied sectors in Union Budget 2024–25

Manufacturing

- **Rising PCI likely** to facilitate higher domestic demand
  - India expected to record highest PCI growth in the world over 10 years
- **Increasing urbanization** set to accelerate need for upgraded infrastructure
  - About $55B annual investment required over the next 15 years to manage infra demand
- **Strengthening of India's positioning as outsourcing destination** driven by global focus on cost reduction and diversification away from China could be beneficial
  - Growing US tariffs on China imports in 2024—100% for EVs; solar cells at 50%
- **Shift to renewables** to necessitate redesign of industrial value chains
  - Renewables accounted for 30% of global electricity generation in 2023

Services

- **Availability of a skilled and English-speaking workforce**
  - 34% of tertiary degree recipients were STEM graduates in 2022
- **Development of digital infrastructure,** enabling rapid digitalization
  - UPI recorded transactions worth more than ₹23T in October 2024
- **Cost competitiveness and availability of skilled tech talent** vs. global players, enabling outsourcing leadership
  - India's strong and cost-competitive engineering talent is driving global capability center (GCC) and outsourcing growth, with GCCs projected to reach about 2,200 by 2030, employing 2.5–2.8 million people

India can draw insights from high-growth sectors in other economies

Agriculture

Brazil: Tech-led improvements and capital accumulation

- **Technology deployment:** Agriculture liming technology deployed to increase grass production per hectare, leading to reduced cattle-raising time
- **Crossbreeding techniques:** Blending of local & foreign genetics improved crop productivity for soybean, cotton
- **R&D:** Significant research-led innovation with about 1% of agriculture GDP deployed (similar to US at 1%–2%)
- **Talent:** Special programs to enable higher education around agriculture research (75% of researchers in agriculture research corporations hold PhDs)
- **International collaboration:** Established bilateral agreements with 56 countries for research/tech transfer

4x
Increase in stocking rate

2–3x
Increase in soybean and cotton yield

Manufacturing

South Korea: Domestic innovation and technology infusion

- **Government-enabled innovation:** Establishment of government research institutes assisted in developing key tech for telecom and semiconductor industries via focused policy of cooperative R&D and partnerships
- **Upstream value chain capture:** Manufacturers first built chip assembly/testing & then moved to higher value mfg. activities, leveraging company partnerships
- **International capability transfers:** Continuous industrial technology upgrades through partnerships with innovative companies (e.g., Samsung)
- **Infrastructure development:** Investments in industrial hubs (e.g., Ulsan), ports (e.g., Incheon port), and transport infrastructure reduced production costs

2x
Growth in high-tech manufacturing value share

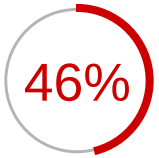
~5%
GDP spend on R&D
(vs. <1% for India)

Services

US: Private sector investment and talent development

- **Efficient licensing markets:** Incentivized knowledge transfer within economy while rewarding innovation
- **Firm-led innovation:** Corporations filing majority patents by leveraging capital base and tech talent for complex R&D
- **Talent development:** Academia and tech firm partnerships, supply of high-quality STEM talent from within/outside US, and easy access to funding for technology start-ups, enabled rapid skilling of workers
- **Private investment:** Growing investment by global tech firms (e.g., Microsoft) to build leadership in new-age products (e.g., AI, Cloud)

30%+
Global market share in IT, info services



Share of global VC funding

Tech trends expected to reshape agriculture, manufacturing, and services sectors

Agriculture

Automated farming and harvesting

Large-scale adoption of machinery to automate farm operations, potentially improving efficiency, reducing labor,
and optimizing yields

Precision agriculture and digitalization

Integration of data analytics, IoT devices empower farmers with precise crop mgmt. insights, optimizing resource use

Hydroponics and vertical farming

Farming methods that enable cultivation without soil even in urban areas, using nutrient-rich water solutions, reducing arable land need

Genetic engineering for resilient crops

Development of genetically modified crops with enhanced traits (e.g., pest resistance, improved nutritional content) to ensure consistent yield

Sustainable agritech

Implementing practices (e.g., carbon farming for soil regeneration, biopesticide usage, solar-powered irrigation) to potentially boost environmental health

Manufac-turing

Hyper automation

AI-driven machines and robotics to handle end-to-end complex manufacturing tasks autonomously with limited human intervention

3D and 4D additive manufacturing

Large-scale use of additive manufacturing techniques to mass-produce customized and adaptive objects

Quantum learning-led supply chain

Leverage quantum tech and deep learning to potentially optimize global supply chains in real time, enabling near-zero waste

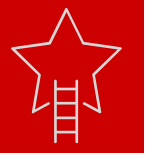
Industrial metaverse

Digital twin integration to simulate entire factories for continuous real-time monitoring and AI-enabled predictive maintenance

Circular manufacturing

Enabling net-zero manufacturing through recycling, reuse, and biodegradable materials that can be safely returned to the environment

Services



AI/ML and generative AI adoption

AI integration to accelerate automation, enhance decision-making, and personalize user experiences across industries

Distributed Ledger Technology (DLT)

Decentralized systems to improve transparency while ensuring security of transactions and supply chains across different services

Advanced comms. (6G and beyond)

Ultra-fast, low-latency, energy-efficient networks that revolutionize communication and data transfer, unlocking transformative applications across industries

Quantum computing

Higher computing power for faster complex problem-solving, from financial modeling to healthcare research, enabling service innovation

Brain-computer interfacing

Direct brain-to-device communication translates neural signals into commands, enabling advancements in communication and human-tech augmentation

Notes: ML = Machine learning; IoT= Internet of Things | Secondary research; Bain analysis

Electronics, energy, chemicals, automotive, and services expected to drive the majority of India's GDP growth

Sector attractiveness Low High *Selected for analysis*

Key sectors	Value addition potential: Gross value add Potential for sector GVA growth until 2047	Value addition potential: Employment Potential for employment growth until 2047	Value addition potential: Export Potential for sector export growth until 2047	India disruption potential: Tech impact Potential for tech to accelerate growth	India disruption potential: India advantage Role of India's traditional advantages and policy in accelerating growth	Overall potential
Agriculture						Moderate value add to GDP, but significant socioeconomic problems (e.g., fragmentation, political hurdles) and affordability limiting tech disruption
Electronics						Large market with high trade-flow, at the core of digital transformation enabling high value-add potential to be part of a generational shift in global supply-chain leveraging India's talent pool backed by strong government incentives to drive innovation and disruption
Energy						Achieving energy and sustainability goals could enhance value addition, while technology-led energy efficiency improvements may drive significant disruption
Chemicals						Export growth especially specialty chemicals to potentially drive high value add while tech-led advancements in value chain to potentially drive disruption
Life sciences						Significant export potential could contribute to GDP, but limited policy support and complex regulations may constrain technological disruption
Automotive						Global shift toward sustainable transport to potentially drive value add; existing manufacturing capabilities poised to drive disruption
Construction and infra						Structural issues including, policy delays and fragmentation, labor issues likely to limit value add, even with tech-led improvements
Services						Outsourcing leadership to continue driving value add while innovation-led tech advancements create strong disruption (esp. in BFSI, retail, healthcare services, tech services, and telecom)

Sectoral deep dives: Electronics

The global electronics landscape is evolving rapidly, driven by AI advancements, cutting-edge manufacturing, and innovative materials/components

ELECTRONICS

1 Near term (next 5 years)

Global geopolitical shift in supply chain
Companies prioritizing domestic production due to geopolitical tensions (e.g., US imports of critical goods from China declined from 18% to 11% from 2017 to 2023)

Smart manufacturing/ Industry 4.0
Smart manufacturing has reduced machine downtime by up to 30%–50% in leading factories

Intelligent devices powered by AI and edge computing
The rapid adoption of AI across industries, combined with edge computing, is transforming user experiences. With approximately **15 billion edge devices** (such as smart cameras) already deployed, this shift is accelerating innovation and real-time intelligence at the device level.

AI-enabled chip design and production
Google's AlphaChip used to generate chip layouts for TPUs, with a 3%–6% average wirelength reduction compared to human experts

Rapidly declining cost of access to AI
New innovative training and inference models to rapidly bring the cost of AI down, making it accessible across industries and use cases

2 Medium term (5–15 years)

Post-silicon electronics
Transition from silicon-based electronics to graphene or other 2D materials, providing breakthroughs in speed, energy efficiency, and miniaturization

Touchless fabrication
Philips has piloted a lights-out manufacturing facility in the Netherlands to produce electric razors with 128 robots and only 9 human workers

Next-generation batteries
Battery tech breakthroughs enable longer-lasting, faster-charging power sources (e.g., TDK researching batteries with 100x energy density)

Development of resilient electronics
Companies (e.g., Apple, Samsung) already hold patents for fully flexible mobile devices as multiple companies continue to develop in this space

Sustainability and circularity
Biodegradable materials and energy-efficient processes to cut e-waste and environmental impact (e.g., Apple aims for supply chain carbon neutrality by 2030)

3 Long term (15+ years)

Additive mfg. and high-tech materials
Use of 3D printing and new-age materials to revolutionize electronics design through precision, functionality, customization, rapid prototyping

Human-machine interfacing (HMI) and neuromorphic chip design
Integration of electronics with human neural networks to allow seamless control and use of devices (e.g., gesture control)

Next-gen connectivity enabling next-gen smart use cases
Rapid growth of advanced communications tech (e.g., LEO satellites) to ensure global coverage, unprecedented speed, and reliability— unlocking use cases such as autonomous transportation, precision farming

Multi-device continuity
Integrated electronics that seamlessly transfer personal data and preferences, offering a personalized user experience (e.g., preconfigured climate control, automated grocery mgmt.)

Notes: LEO = low-Earth orbit; TPU = tensor processing unit
Sources: Secondary research; Bain analysis

Major technology advancements could potentially transform India's electronics industry by 2047

ELECTRONICS

		Trend	Impact	Current developments around the world
Near term	**AI-enabled R&D and fab design**	AI-led product simulation and trials, fab plant design, and supply chain optimization to save time, resources	**Faster and accurate experimentation and production**, reducing costs and shortening time-to-market	EDA tool vendors are introducing AI/ML-based software (e.g.,Fab.da) to make semiconductor manufacturing efficient using data and insights from the entire lifecycle of development
	Low-power electronics	Devices designed to operate with minimal energy consumption while maintaining functionality and efficiency	Impactful **reduction in energy consumption** (data center electricity demand [1%–2% of current global use] expected to double by 2026)	Chip vendors are moving from traditional silicon to silicon carbide (SiC) and gallium nitrate (GaN) that offer better power efficiency across a wide variety of applications such as data centers, EV charging, renewables, and industrial drives
	Biodegradable components	Components that use biodegradable raw materials and decompose into non-toxic substances after disposal	Significant **decrease in e-waste** production and subsequent environmental pollution (India produced 4 billion kg of e-waste in 2022)	Researchers are working on biodegradable circuit boards using cellulose nanofibers derived from natural sources like wood pulp
	Flexible and trans-parent displays	Screens that can be embedded in non-rigid materials (e.g., clothing, everyday surfaces)	**Products to become versatile and adaptable** given integration with built-in flexible electronics	Companies (e.g., Samsung, Apple) are pioneering flexible display technology with foldable smartphones and rollable OLED screens
	Touchless fabrication	Use of autonomous robots and IoT systems to fabricate chips end-to-end without any human intervention	**Improved precision,** and reduced contamination and costs given limited human intervention	TSMC has implemented advanced tech to enable intelligent fab automation, reducing production errors
	Additive mfg. and adv. materials	Use of additive manufacturing (3D printing), along with materials (e.g., carbon/graphene nanotubes to build components)	**Rapid large-scale manufacturing** with **enhanced performance and miniaturization** of electronic components	Nano Dimension is building 3D printers that can print conductive inks and dielectric materials layer-by-layer to build printed circuit boards, sensors, other components
Long term	**Quantum and neuromorphic computing**	Design of quantum computers and brain-inspired neuromorphic chips to power new computing paradigms	**Increase in processing power** enabling complex computation and analysis of large data sets	Intel developed an experimental neuromorphic chip called Loihi to aid in computational neuroscience efforts

India needs to strengthen infrastructure and scale adoption of emerging technologies to compete with global electronics leaders

ELECTRONICS

Key learnings from global peers

Malaysia

Tax incentives and financial subsidies to boost domestic production

- Tax incentives for electronics companies with 60% capex offset against 70% income, and a 15-year tax exemption for new manufacturing and R&D firms
- As part of the National Semiconductor Strategy, the government has set aside a more than $200 million sovereign fund for the electrical and electronics (E&E) sector
- The government has also introduced an Industry4WRD Fund to support SME upgrades, with about 50% capex subsidy

Vietnam

Favorable trade policies to encourage exports and secure upstream supply chain, maintaining global leadership

- Vietnam allows duty-free imports of input parts to drive exports at competitive prices and offers a five-year import tax holiday for materials used in industrial parks and Export Processing Zones (EPZs)
- Vietnam has made good use of its free-trade agreement to eliminate tariffs and drive demand from developed countries (e.g., European Union)
- Vietnam provides access to large manufacturing clusters along with incentives such as tax, tariff and rent exemptions to attract scale manufacturers

China

Heavy R&D and tech ecosystem investment to ensure continued innovation and gain global thought leadership

- China offers significant funding support in addition to the development of state-level engineering tech research centers and labs, and a 50% subsidy in R&D costs for manufacturing
- The government also offers a 200% R&D expense deduction to ensure IP stays in China
- China's cost of capital is among the lowest (3.25%–4.75%), backed by strong equity financing for small businesses, fostering easy access to capital for innovation and expansion.

Taiwan

Industry-academia partnerships and **skilling initiatives** to attract and develop skilled workforce

- Taiwan has introduced a Recruitment and Employment of Foreign Professionals Act to retain talent
- The government also offers several scholarships and encourages industry-academia collaboration by endorsing programs such as the Industry Academia Innovation School (IAIS), which is a joint venture between National Yang Ming Chiao Tung University (NYCU) and leading companies like TSMC and Foxconn to bridge the gap between academic research and industry needs
- India's R&D spend is less than 1% of GDP (vs. Taiwan, which is ~4%)

Learnings for India

Facilitating domestic semiconductor production by potentially exploring competitive tax incentives and financial support for entrants

- Providing tax credits for that could enhance in-house R&D spending in India
- Current PLI schemes focus on assembly, with need for end-to-end PLIs that could incl. component mfg. in their ambit

Making Indian exports competitive by potentially exploring simplification of tariff structures, rationalization of duties

- **4–6 percentage points higher free trade agreement and most favored nation tariff** average in India vs. China and Vietnam might be pivotal

Develop the manufacturing ecosystem via measures that could include funding & tax incentives

- **Devise favorable policies that could promote design-led manufacturing** and create a conducive environment for doing business in the country

Pursue **cluster-led development, providing supporting infrastructure** to potentially accelerate domestic manufacturing via plug-and-play facilities

Focus on industry-academia collaboration and **vocational skilling initiatives** for potential innovation and manufacturing leadership vs. global peers

- Invest more in Industry-academia collaborations by offering scholarships for students and researchers under the IESA (India Electronics and Semiconductor Association) schemes
- Demand for skilled talent via vocational training rather than academic degree focus is a path worth exploring

To grow its electronics sector, India can accelerate domestic production, increase participation in the global value chain, develop new clusters, and invest in skilling

ELECTRONICS

India as manufacturing hub

- While the overall domestic consumption grows**, India could potentially strengthen the electronics ecosystem by**
  - Reducing high dependence on imports (about $78 billion)
  - Incentivizing local players to scale up by offering tax incentives and subsidies
  - Introducing attractive policies for manufacturing companies to invest more in R&D
- Driven by global realignment, better manufacturing ecosystem and momentum of global players moving to India, **electronics market has the potential to grow to $3–$3.5T by 2047**

Greater participation in global value chain

- Even though 75% of electronics exports are part of global value chains, **India currently is at less than 1% share in the $3T electronics trade** flow globally
- Backward integration into component mfg. & design to **improve cost competitiveness & domestic innovation,** could potentially ensure strong participation in the global value chain
  - Undertake interventions to potentially improve cost competitiveness, reducing cost disability for India from high tariffs on input components, compliance (e.g., favorable FTA agreements with global demand centers, PLI with capex subsidies)
  - Develop global champions by creating a platform for development across the value chain which could include design/ODM and assembly (e.g., Jabil), component manufacturers, OEMs (e.g., Apple)

Development of new clusters

- **Electronics production currently concentrated in four clusters:** Karnataka, Maharashtra, Uttar Pradesh, and Tamil Nadu
- Development of **large-size clusters pan-India**, with localized regulations to potentially leverage cost economies and improve welfare outcomes could be considered

Electronics-led job boom

- Focus on domestic production and shift toward design and manufacturing could potentially **create 20–22 million jobs and raise labor productivity**
- Investing in **skilling and tech transfer** could enable this transition

From (2023)		To (2047)
$100B	15%–20% CAGR →	$3–$3.5T
	Domestic production	
3%	→	8%–10%
	Share in GDP	
24%	→	45%–50%
	Percentage of exports in production	
2%	→	>20%
	Percentage of global production	
1.8M	→	20–22M
	Number of jobs	

Note: OEM = original equipment manufacturer

The electronics sector should aim to must address several challenges to grow

ELECTRONICS

1 Near term (next 5 years)

Supply chain disruptions and component shortage

- Ongoing scarcity of semiconductors affecting production timelines, leading to increased costs
  - In 2021–22, global chip shortage led to multiple firms either shutting down completely or curtailing production
- Global supply chain bottlenecks and logistics issues are further delaying lead times

Regulatory and compliance challenges

- Indian firms need to keep up with rapidly evolving global and domestic regulatory standards
  - US Customs and Border Protection detained about $43M of Indian electronics shipments under Uyghur Forced Labor Prevention Act since Oct 2022 (Indian manufacturers failed to meet compliance)
- IP protection and enforcement regulation has potential to get stronger for Indian players to innovate and compete globally

2 Medium term (5–15 years)

Inadequate infrastructure and manufacturing capabilities

- Currently concentrated in low value-add assembly stages leading to high-cost disadvantage vs. global leaders like China (10%–15% lower costs)
  - Cost disadvantage due to higher tariffs, freight costs, reliance on high-priced imported components coupled with lower subsidies for tech transfer via foreign investments
- Inadequate infrastructure vs. SEA countries for chip design and fabrication, leading to operating inefficiency
  - Need for investment in world-class facilities (e.g., TSMC's fabs in Taiwan) to drive innovation at scale

Limited R&D and innovation ecosystem

- Insufficient R&D investments, with companies needing significantly more funding to drive innovation
  - Talent supply gap in advanced manufacturing skills (incl. high-tech areas like AI, IoT),possibly leading to cost escalation for OEMs
- Weak collaboration between industry, academia, and research institutions, limiting innovation
  - Limited joint initiatives between leading universities (e.g., IITs) and major electronics firms, in contrast to other global leaders

3 Long term (15+ years)

Dependence on imports incurring risk of global economic instability

- Heavy import dependence for components (e.g., China, Vietnam), leading to vulnerability due to geopolitical tensions, trade restrictions, black swan events
  - For example, import dependence for high-quality PCBs with more than 8 layers, displays, microprocessors, battery cells
- Reliance on countries for raw materials for electronics mfg. (e.g., lithium, cobalt, nickel for battery manufacturing; silicon wafers for semiconductors)

Sustainability pressures

- Growing volume of e-waste necessitates robust recycling policies and infrastructure
  - 3.2 million tons of e-waste were generated in India in 2019, of which less than 20% was formally recycled
- Increasing demand for environmentally friendly production methods and transition toward renewable energy sources
  - For example, Samsung wants to achieve enterprise-wide net-zero emissions by 2050

Notes: IoT = Internet of Things; SEA = Southeast Asia; IIT – Indian Institute of Technology; PCB = printed circuit board

Some potential levers to ensure robust growth of the Indian electronics sector

ELECTRONICS

		Current state	Potential levers
Near term	**Smart factories to unlock productivity**	**10–14x** labor productivity for China compared to India	• **Leverage Industry 4.0 tech** (e.g., IoT, robots, digital twins, AI/ML) to automate design and fabrication processes and enhance OEE via measures that can include reduced defects, increased uptime, and predictive maintenance – Potential to use generative AI in layout planning and process design to enhance overall efficiency of chip manufacturing process – China leveraged large-scale tech adoption, capacity expansion to gain global leadership; India can leapfrog by embracing emerging tech
	Generative AI to accelerate hard infra development	**3 years** Time taken to ramp up fab from design to production in India	• **Leverage generative AI to potentially accelerate infra setup** (e.g., optimize design and construction process, refining SOPs) – Integrating generative AI in planning and design has potential to reduce the setup time to 1–1.5 years, while driving cost efficiencies (Developed nations yet to crack this problem as fab setup takes 3–4 years across the world)
	Tech as an enabler to optimize business processes	**7–10 days** Time for customs clearances for exports	• **Leveraging digital platforms enabled via AI** to efficiently manage day-to-day processes across domains – Regulatory and compliance management: IP registrations, approvals, licensing, and permits applications management – Finance: working capital management, receivables planning and forecasting, accounting, and audit management – Logistics: logistics planning including route and mode of transport, inventory planning, and demand forecasting
	Sovereign AI to strengthen India's tech stack	**<2.0%** India's share of global computing power	• **Develop sovereign AI models** for R&D and product simulation to potentially reduce dependence on global models – Model allows optimization for localized context and languages, and ensures data protection for industrial AI use-cases • **Democratizing technology access by potentially exploring subsidized access to computing infrastructure for Indian start-ups, which could include GPUs and data centers** – For example, GoI initiative to invest approximately $600 million in high-end Nvidia GPUs as part of the India AI Mission
Long term	**R&D investment in emerging technologies**	**0.4%** India's share of electronics PCT publications (China 34%, US 19%)	• **Invest in R&D to potentially attain leadership in new technologies** (e.g., flexible electronics and neuromorphic chips) – Undertake research in nascent technologies such as quantum tech, which can help develop better materials for electronic components, enhance computational power, and fuel innovation in high-performance electronics • **Focus on integrating sustainable practices across the manufacturing value chain** – Using biodegradable raw materials to reduce e-waste and researching adoption of circularity across the manufacturing process

Notes: IoT= Internet of Things; ML = machine learning; OEE = overall equipment effectiveness; SOP = standard operating procedure; GPU = graphical processing unit; PCT = patent cooperation treaty; GoI = Government of India
Sources: Secondary research; Bain analysis

Sectoral deep dives: Energy

The global energy landscape is evolving, driven by clean energy, infrastructure enhancements, and new consumption behaviors

ENERGY

1 Near term (next 5 years)

Accelerated solar/wind deployment
Solar photovoltaic (PV) and wind are forecasted to account for 95% of renewable capacity additions through 2030—driven by declining costs, supportive policies

Carbon pricing and regulatory shifts
More than 50 countries have implemented carbon pricing mechanisms to potentially reduce GHG emissions

Battery storage expansion
Fastest-growing energy technology to meet the growing demand for renewable energy integration, grid stability

Energy efficiency
At COP28 in 2023, about 200 countries agreed to double the global average annual rate of energy efficiency improvements by 2030

2 Medium term (5–15 years)

Grid modernization
Steady growth in grid investment after over a decade of global stagnation—with emphasis on digitalizing and modernizing distribution grids

Electrification of transportation
2/3 of all vehicles sold in 2035 could be electric, avoiding around 12Mbbl/d of oil

Hydrogen economy development
Green hydrogen market expected to grow from $10 billion today to $180 billion by 2035

Distributed energy & decentralization
DER capacity, including rooftop solar, batteries, and microgrids, expected to grow by over 60% by 2030

Waste energy/biofuels
Regulatory mandates (e.g., EU's Fit for 55 package aim for 63% reduction in transport emissions by 2030)

3 Long term (15+ years)

Renewable energy dominance
90% of world's electricity to come from renewable energy by 2050—International Renewable Energy Agency (IRENA) estimates

Advanced nuclear technologies
31 nations have endorsed Declaration to Triple Nuclear Energy Capacity by 2050 led by research in small modular reactors, fusion tech

Autonomous and connected energy systems
Wide-scale adoption of autonomous energy systems, leveraging AI and IoT for efficient energy management and grid optimization

Notes: GHG= greenhouse gas; DER = distributed energy resource; IoT = Internet of Things
Sources: Secondary research; Bain analysis

Major technology advancements could potentially transform India's energy industry by 2047

ENERGY

		Trend	Impact	Current developments around the world
Near term	**Renewable energy storage solutions**	Advanced storage technologies (e.g., sodium ion batteries) could enhance grid stability by storing excess renewable energy for use during low generation periods	Could enable long-duration storage, cuts fossil-fuel reliance, and strengthens grid resilience for large-scale renewable adoption	Natron Energy to build a large-scale sodium-ion battery manufacturing plant ($1.4B) in Edgecombe County, North Carolina, to address the growing demand for energy storage solutions in the US
	Smart grids	AI-controlled smart grids could efficiently manage energy distribution	Could greatly minimize energy wastage and improves accessibility and affordability	Global smart grid investments currently at ~$300B annually, according to IEA, driven by efforts to modernize energy infrastructure, enhance grid resilience, and integrate renewable energy at scale
	Carbon capture and utilization	Innovations in carbon capture could convert emissions to produce synthetic fuels, chemicals, and graphite and enhance oil recovery	Could promote a circular economy and support efforts for overall decarbonization of industries and the environment	The U.S. DOE's Office announced the selection of nine university & industry projects to receive $44.5 M in federal funding for commercial-scale carbon capture, transport, and storage across USA
	Microgrids	Decentralized, self-sufficient energy systems that can operate independently or alongside the main grid, often powered by renewable energy sources	Could support energy access in remote areas, improve energy resilience, reduce reliance on centralized grids, and enhance local energy security	US-based power generation businesses have adopted microgrids to counter increased outages, with cumulative installed capacity reaching 5.4 GW in 2023
	Small modular reactors (SMRs)	Targets high-energy use cases (e.g., data centers) with advanced nuclear reactors with a compact design, capable of assembly and deployment in modules	Potentially offering flexible, scalable, and safer options for generating nuclear energy, enabling higher adoption of low-carbon energy production methods	In a major step towards decarbonizing data center operations, Google announced agreement to purchase nuclear energy from small modular reactors (SMRs) developed by Kairos Power
Long term	**Nuclear fusion as an energy source**	Practical fusion could provide clean energy source with significant changes in tech in multi-decades	Could drive breakthroughs in energy availability and eliminate the need for traditional sources. Net energy fusion is possible in a decade with recent progress in magnets and alternative reactors; however, commercialization is still uncertain	Commonwealth Fusion Systems (MIT-based research company) is using plasma physics and superconducting magnets to explore nuclear fusion technologies

Note: MIT = Massachusetts Institute of Technology, NREL = National Renewable Energy Laboratory, IEA = International Energy Agency | Sources: Secondary research; Bain analysis

To compete globally, India should target increasing its energy investments and introducing supportive regulations

ENERGY

Key learnings from global peers

China

Focused government incentives could accelerate clean energy adoption and innovation

- China established the largest solar and wind energy capacity through government incentives, subsidies, and favorable regulations (e.g., in 2010s, China set attractive FIT rates for solar projects, to incentivize investments)
- Encouraged innovation in solar cell mfg., leading to cost competitiveness vs. global players (about 10% lower costs vs. India with high-efficiency crystalline silicon cells improving conversion efficiency by 25%)

European Union

Significant investment in grid modernization and smart grid technologies

- EU has invested about $5.3 billion in smart grid projects from 2002 to 2015, with investments helping enhance grid reliability and integration of renewable technology

Australia

Focus on energy storage expansion and solutions to ensure grid stability

- Leadership in grid-scale battery storage (30% of global battery storage demand in 2019) with plans to install 27 GW of grid-scale batteries by 2050—driven by strong renewable energy targets

Japan

R&D investment in emerging energy technologies, including hydrogen and advanced nuclear power

- Government's hydrogen strategy highlights nine key tech (e.g., fuel cells, water electrolysis devices) with plans to invest about $100B in next 15 years to boost hydrogen use to 12M tons per year by 2040
- In 2023, the Japan Atomic Energy Agency, Mitsubishi Heavy Industries, Mitsubishi FBR Systems, and US-based TerraPower expanded their collaboration on sodium-cooled fast reactor technologies to advance nuclear energy capability

Learnings for India

Clean energy adoption could be potentially boosted by exploring implementation of robust policies and incentives

- Strengthening renewable energy targets and introducing policy stability could attract investments
- Provide subsidies and tax benefits for solar, wind, and other renewable energy projects for potential growth in adoption

Investing in grid modernization and smart grid tech could be important

- Enhance grid reliability and facilitate the integration of renewable energy sources
- Implementing advanced metering and demand response systems could improve energy efficiency

Develop comprehensive energy storage strategy

- Fund energy storage projects and R&D in battery tech
- Stability and reliability could be ensured by potentially promoting grid-scale storage solutions

Foster innovation in emerging energy technologies

- Consider increasing funding for R&D in hydrogen, advanced nuclear, and other next-gen energy solutions
- Collaborate with global leaders to transfer technology and best practices

Notes: FIT= feed-in tariff; FBR = fast breeder reactors
Sources: Secondary research; Bain analysis

To grow its energy sector and fuel rapid economic expansion, India needs to modernize its energy infrastructure and invest in green energy

ENERGY

	From (2023) → To (2047)
Shift toward green energy (solar and wind)	• India has continuously invested in renewables and currently ranks **fourth globally in cumulative installed wind power capacity** and **fifth in terms of total solar installations** • This shift is in line with India's commitment to achieve about 50% of power generation fueled by non-fossil sources by 2030, and ultimately reach **net-zero emissions by 2070**	**24%** → **~70%** Share of renewables in the overall electricity generation in STEPS scenario
Digital revolution (modernized grid and value chain)	• Reliability could be ensured by potentially investing heavily in modernizing grid infrastructure in order to meet increasing pace of electrification and accelerated deployment of renewable deployment • **Digital technologies** (e.g., AI, Internet of Things, drone, smart meters) have a variety of applications, driving efficiency across the value chain of construction, generation, maintenance, transmission, distribution	**~8%** → **~100%** Share of smart meters
Transition to smart grids	• India is advancing toward a **nationwide smart grid transition** to enhance grid reliability, reduce transmission losses, and support the integration of renewable energy sources • In 2021, the government rolled out smart meter tenders for the installation of more than 250 million smart meters by 2025	**~$1.2B** → **~21.8B** Annual spend on smart grid solutions and services
Renewable energy value chain participation	• Current participation in the renewable energy transition is limited; however, with planned investments, India could emerge as one of the leaders in manufacturing for solar manufacturing—cells, panels, wind turbines, batteries, energy grids—and play a key role in the **global renewable energy supply chain**	**Net importer (~ 85% demand)** → **Net exporter** Share of imports as percentage of India's solar module consumption
Renewable energy-led job boom	• This transition may also create many **semi-skilled jobs** in manufacturing, construction and **highly skilled jobs** in network design, tech, and more • Investing in **skill development and apprenticeship initiatives** is potentially critical to enable this transition	**~1M** → **~ 3M** Renewable energy jobs

Notes: STEPS refers to Stated Policies Scenario which is designed to provide a direction of energy system progression based on a detailed review of the current policy landscape
(1) Smart Grid Services include deployment enablers such as consulting, project management, digital grid management, advanced metering infrastructure, which consists of hardware and software like smart meters and meter data management
(2) Smart Grid Communication includes software, hardware, and network equipment that enable two-way communication across electricity transmission and distribution grids. It also encompasses smart grid security solutions, which involve software components designed to enforce cybersecurity Sources: Secondary research; Bain analysis

The energy sector should aim to address several challenges to grow

ENERGY

1 Near term (next 5 years)

External dependencies
- High dependency on imports for fossil fuel (87.7% crude oil and 22% coal imported) and solar components (73% of solar PV cells and modules were imported from China in Q1 2024)
- Reliance on peers (e.g., China) for components and minerals to support local battery and energy storage market (70%–80% of lithium demand met via imports)

Sub-par energy infrastructure
- Slow adoption of smart grid tech, energy efficiency measures, and digital solutions to optimize energy use
  - India has set a target of 12%–15% AT&C losses under the RDSS; India achieved 17.6% AT&C losses in FY24
- Complexity in managing fluctuations from solar cells and wind turbines (2–3x variability in peak vs. lean season)

DISCOM instability
- Locking DISCOMs into long-term deals at predetermined rates, limits flexibility to use lower price on exchanges

Regulatory complexity
- India has over 20 central and state-level agencies involved in energy governance

2 Medium term (5–15 years)

Private sector participation
- Investment in renewables largely led by private sector, with this trend expected to continue in mid-term
- For example, Tata Power looking to invest about $9B on renewable energy with 15GW additional renewable capacity to be added by 2030

Workforce and skill needs
- Significant gap of about 1.2 million workers needed for transition to renewable energy (higher percentage of medium/high-skilled professionals required)

Waste management
- Managing waste from energy production to become more critical (including nuclear waste, electronic waste from solar PV systems)
  - Solar PV waste volume expected to rise to 340KT by 2030

3 Long term (15+ years)

R&D and energy project financing gaps
- India's investments in R&D programs at 0.6% of its GDP as compared to major economies like US at 3.5%, Germany at 3.1%, and China at 2.4%
  - India needs $400 billion in investments in renewables by 2030 as per IREDA[1]

Alignment with international climate commitments
- Need to reduce emissions in line with global climate commitments (e.g., Paris Agreement goal to achieve net-zero emissions by 2070)

Notes: 1. IREDA = Indian Renewable Energy Development Agency; PV = photovoltaic; RDSS = Revamped Distribution Sector Scheme; AT&C = Aggregated Transmission and Commercial
Sources: Secondary research; Bain analysis

Some potential levers to ensure robust growth of the Indian energy sector

ENERGY

		Current state	Potential levers
Near term	**Rise in consumption driving decentralization and need for reliability**	**3.7** annual average outage hours per customer in 2019 (vs. 2.1 for China) **6.4M+** people still don't have electricity access	• **Deploy smart grids to improve reliability** – Need to build more resilient energy systems for potentially increasing consumption (e.g., smart grids to improve reliability, reduce transmission losses, optimize demand management, and ensure efficient grid usage) – R&D and IT investment needed for real-time data collection (via smart meters), secure communications using RF-2.4 GHz, building data concentrators, and piloting systems like smart grid control centers (SGCCs) and outage mgmt. systems (OMSs) • **Invest in developing a decentralized grid network** – Adoption of distributed energy infrastructure such as rooftop small-scale solar, home battery systems, and digital mini-grid solutions (e.g., mobile-off-grid solar) could provide access to remote areas via local distribution
	Renewable transition and upstream participation	**8%** rise in fossil fuel consumption over 2023	• **Identify next-gen materials via innovation** (e.g., wind turbines); scale up alternative fuel cell tech – Govt to provide incentives and subsidies which could encourage firms to invest in next-gen technology for R&D • **Adopt alternate energy tech** (e.g., hydrogen tech to use hydrogen as an alternative to fossil fuels in industries)
	Improving efficiency in setup and operations	**2x** T&D losses in India compared to global average	• **Research use cases with new-age tech** (e.g., IoT, digital twins, analytics, and edge computing) could improve efficiency via smart grid mgmt. (i.e., demand, supply prediction, load balancing), predictive maintenance (i.e., failure risk prediction), grid design optimization
	Green hydrogen as an energy and storage solution	**3%+** annual increase in energy demand expected up to 2030	• **Develop green hydrogen tech as high-power density energy and storage solution** for India – Focus on using surplus agricultural biomass to generate green hydrogen; India's National Green Hydrogen Mission has set a target of 5 million MT annual production capacity of green hydrogen (making India a net exporter) and generating 600,000 jobs by 2030
Long term	**CCUS to achieve net-zero goals**	**3rd largest** CO_2 emitter globally	• **Implementing carbon capture and storage tech could reduce carbon intensity and achieve net-zero emission** – Aim to develop technology to fully utilize up to 400 billion tons of potential carbon storage potential, in geological formations such as coal fields, oil and gas fields, sedimentary basins, and saline aquifers

Notes: T&D = theft & distribution; IoT = Internet of Things; MT = metric tons; CCUS = carbon capture utilization and storage | Sources: Secondary research; Bain analysis

Sectoral deep dives: Chemicals

The global chemicals landscape is evolving rapidly, driven by sustainability, advanced manufacturing, and innovative materials

CHEMICALS

1 Near term (next 5 years)

Inventory overhang
Slower demand is resulting in surplus inventory, prompting capacity rationalization to optimize operations
- About 10% potential global capacity reduction as EU and SEA plants close due to high costs and low demand

Supply chain de-risking
Shifts in global manufacturing away from Europe China driven by cost and supply chain resilience
- Europe +1: Relocate plants driven by cost hikes in raw material and labor
- Derisk supply chain from geopolitical tensions

Renewable feedstock integration
Raw material sourcing from renewable resources to reduce carbon footprint
- Renewable hydrocarbons expected to reduce GHG emissions by about 85% vs. fossil feedstock

Continued focus on safety
Implementation of advanced tech (e.g., IoT sensors, AI-driven predictive maintenance) to enhance safety amid stricter regulations and stakeholder scrutiny

2 Medium term (5–15 years)

Capacity redesign toward specialty
Shift in capacity toward high-value specialty chemicals to meet rising end-user industry demand
- For example, battery materials, composites, and adhesives support EV, solar, wind industry growth

Digitally integrated processes
Scaled integration of tech (e.g., IoT, robotics, AI, digital twins) to accelerate R&D, optimize production processes and enhance operational efficiency
- Chemical industry expected to spend more than $7B on plant digitalization by 2031

Advanced additives
Advanced materials to improve process efficiency and product performance
- For example, nano-catalysts that accelerate reactions, lowering production costs and emissions

Sustainability and circularity
Adoption of circular economy to minimize waste and enhance resource efficiency
- Chemical recycling tech to convert plastic waste back into raw material (e.g., BASF's ChemCycling project)

3 Long term (15+ years)

Next-gen materials
Large-scale development of advanced functional materials for specialized applications
- For example, materials that are self-healing, conductive, or responsive to temperature and pressure changes

Net-zero chemicals production
Progressing toward carbon neutrality through renewables, efficiency, and carbon capture
- More than 70% of the world's top 100 chemicals producers have committed to carbon neutrality by 2050

Biodiversity preservation
Formulating environmentally benign production processes to preserve biodiversity near plants
- BASF is pioneer of Rainforest Alliance Certified personal care ingredients to protect freshwater ecosystems by reducing aquatic toxicity
- Use of biological processes for chemicals mfg. (e.g., engineering microorganisms that naturally synthesize target chemicals)

Notes: IoT = Internet of Things; GHG = greenhouse gas
Sources: Secondary research; Bain analysis

Major technology advancements could potentially transform India's chemicals industry by 2047

CHEMICALS

		Trend	Impact	Current developments around the world
Near term	**Circular economy integration**	Closed-loop systems where waste chemicals are reused to create new products	**Reduce discharge of potentially harmful waste** by enabling reuse/recycling, leading to lower raw material consumption and waste costs	BASF has implemented an initiative (ChemCycling), where the company is recycling plastic waste or end-of-life tires into secondary raw material (pyrolysis oil)
	Green chemistry	Sustainable, zero-waste chemical production with biobased inputs and CO2 emission recycling	**Decreases the environmental footprint** of chemical manufacturing processes and improves sustainability	LanzaTech has developed tech that captures carbon emissions from industrial sources and converts to valuable chemicals
	Wearables for safety monitoring	Use of IoT devices and sensors to continuously monitor the worker's environment and raise safety alarms	**Enhances workplace safety** in a relatively hazardous working environment	Shell leverages AI-driven technology to detect and alert on unsafe behaviors via camera-driven computer vision and smart wearables
	Industrial metaverse with AI-enabled maintenance	Digital twins will simulate entire factories for real-time monitoring and predictive maintenance	Improve efficiency by **minimizing equipment failures** while reducing human presence near dangerous chemicals	Siemens has developed digital twin technologies for chemicals greenfield and brownfield production
	Nanotechnology for material synthesis	Atom-level material synthesis, leading to ultra-durable and versatile materials	**Reduces material usage** by enabling atom-level precision in mfg., while producing **customizable materials** for specialized applications	Arkema offers range of carbon nanotubes and copolymers capable of imparting new properties to thermoplastics by modifying molecular structure at nanometric scale
Long term	**Self-assembling and smart polymers**	Development of biodiversity-safe materials using AI that can adapt to environmental changes and self-repair	**Reduces maintenance needs and improves durability**, with potential applications in industries (e.g., aerospace)	MIT researchers are studying self-assembling polymers for industrial use, which could lead to new applications in various sectors

Notes: MIT = Massachusetts Institute of Technology; IoT = Internet of Things | Sources: Secondary research; Bain analysis

To compete globally, India may cultivate national champions and innovate

CHEMICALS

Key learnings from global peers

China

Cultivation of national champions to compete with the global market
- Twelfth five-year plan approved in 2014 laid out policies to increase China's self-sufficiency in chemicals via designation of national champions (e.g., Wanhua)

Consolidation of mfg. resources into chemical parks to take advantage of economies of scale
- China has designated over 720 chemical parks to allow better supervision of the industry and implement tightened environmental protection

Canada

Concerted efforts to ensure supply chain resilience in the long term
- Canada growing presence in EV supply chain by leveraging its naturally occurring raw materials (nickel, copper, lithium, and other rare earth elements), extensive mining experience, and sustainability norms
- Since 2020, Canada has received more than $46 billion in investments across EV supply chain as companies prefer stringent environmental, social, and governance (ESG) standards (83% carbon-free electricity grid)

Brazil

Focused initiatives to encourage sustainable development and use of green chemistry principles in manufacturing processes
- Brazil offers additional tax relief for adoption of sustainable manufacturing practices and renewable feedstock (e.g., a planned hydrogen tax credit law setting aside $3 billion in tax credits for companies producing or consuming low-carbon hydrogen)

Germany

Implementation of public-private partnerships (PPPs) to encourage collaboration between industry, academia, and government organizations
- R&D spending for German chemicals companies reached $15 billion in 2023 as PPPs allowed for fast-tracked innovation across the sector while ensuring adherence to sustainability and other regulatory norms
- Chemie3 is a well-established PPP that aims to support companies in their journey toward environmental protection and compliance

Learnings for India

Promoting the **growth of large domestic chemical companies** through consolidation and strategic policies could be a potential lever to strengthen self-sufficiency and global competitiveness

Strengthening partnerships with resource-rich nations and **exploring domestic untapped reserves** could potentially help reduce existing Chinese imports
- Investing in refining infrastructure for lithium, nickel, and cobalt could help reduce raw material imports
- Promoting R&D in advanced battery chemistry (e.g., SSBs) could offer alternatives to lithium-ion technology

Incentivizing implementation of green chemistry principles and sustainable manufacturing practices could be important
- Potential for India to enter new markets with green alternatives to petrochemical feedstock

Leveraging PPPs could potentially enable effective collaboration between government, industry, and academia to drive R&D and sustainable innovation

To grow the chemicals sector, India can accelerate exports, increase upstream participation, and pursue technology-driven improvements

CHEMICALS

Momentum in production

- Indian chemicals market could **grow at 8%–9% CAGR to reach $1–$1.5 trillion by 2047**, specialty chemicals segments to become the fasted growing sectors
  - Factors driving growth include growth in downstream industries in manufacturing, climate-change policies driving a requirement for specialty chemicals
- **Export growth driven by narrowing China-India cost differential; strong government support** through PLI schemes aiming to reduce costing by 10%–20% to tackle the 5%–10% cost disadvantage

Global competitiveness via focused positioning and scale

- **Potentially increase share in rising domestic market and expand global presence** via three key levers:
  - Targeted play for competitive advantage: Achieve global leadership in commoditized offerings (like Shin-Etsu for Silicon) or R&D-led differentiated play in areas of technology expertise
  - Capex investments to build scale: Leverage govt. subsidies and policy support could accelerate expansion and scale operations
  - Technology, ops excellence for cost leadership like real-time capacity planning, quality improvements via automated material handling, energy consumption optimization, digital twins for process optimization, and more

Upstream participation

- While India has a strong presence in end products for specialty, agrochemicals, there is a **viable opportunity to move up the value chain**, expanding to building block chemicals, intermediate products
- India could **invest in upstream resources and identify opportunity spaces where having an upstream play could be important strategically** (e.g., how Canada has established a key position in lithium-ion batteries, recycles lithium, and is integrated with the US auto industry)
- India could **develop capacity for green sources of feedstock** to reduce dependence on fossil fuels (e.g., green hydrogen for ammonia)

Technology-led productivity improvements

- **Technology could play an active role in enabling companies to improve productivity** for example, efficiency in mfg. setup and ops. (e.g., digital twins, smart factories), reliability (e.g., supply chain planning), yield
- **India could move towards becoming a key chemicals innovation hub** for the world with 1) R&D labs set up by global and Indian companies, 2) Supportive regulations and CoEs, 3) Skilling initiatives

From (2023)	→	To (2047)
~$180B	→	$1–$1.5T
Domestic production for chemicals		
26%	→	40%+
Share of specialty chemicals in production		
~20%	→	35%–40%
Share of exports in domestic production		
0	→	3–5
Enterprises with greater than $10 billion revenue		
<3%	→	10%+
GVC share (percentage)		

Note: PLI = productivity-linked incentives; CoE = center of excellence; GVC = global value chain | Sources: Secondary resources; Bain analysis

The chemicals sector should aim to address several challenges to grow

CHEMICALS

1 Near term (next 5 years)

Inconsistent access to essential raw materials

- Geopolitical tensions and trade restrictions disrupt global supply chains
  - Dependence on rare earth elements from specific regions (e.g., China) creates supply chain vulnerabilities (about 50% basic and intermediate chemical imports from China)
  - BASF India profitability impacted by about 15% in Q2 FY25 on the back of higher input costs

Regulatory challenges and environmental compliance

Delays in environmental clearances and complex regulations contribute to project slowdowns and higher compliance costs

- e.g., CBAM[1] regulation could impose tariffs if environmental standards are not met—to be in effect in the EU from 2026

2 Medium term (5–15 years)

Fragmented market with sub-scale domestic players

- India's market is highly fragmented, dominated by sub-scale players primarily focused on domestic sales

Transportation and logistics challenges

- Limited pipeline connectivity and inadequate facilities at ports and railway terminals pose transportation challenges (Pipeline length in US 64x vs. India)

3 Long term (15+ years)

Insufficient R&D and skilling investments

- Limited funding and skilled workforce availability hinder large-scale research, innovation, and operations
  - China has 47 national chemicals parks compared to only 4 for India

Effective disposal and recycling

- Inadequate waste management and recycling practices risk environmental and public health
  - More than 15 million metric tons of hazardous waste generated in 2023, of which only about 8 million utilized or recycled
  - Several CPG companies have committed to investing $56 million in advanced recycling tech to manage single-use plastic waste in India

Note: 1. CBAM = Carbon Border Adjustment Mechanism
Sources: Lit search; Bain analysis

Some potential levers to ensure robust growth of the Indian chemicals sector

CHEMICALS

		Current state	Potential levers
Near term	**Advanced safety systems**	**130** major chemical accidents from 2013–22	• **Regular upgrades of safety systems**, aligning with global standards through digital audits, wearables for worker safety, AI alerts for early alarms and real-time risk mitigation
	Sustainability across value chain	**4%** Chemical sector contribution to India's GHG emissions	• Leverage **technology for plant-level carbon footprint tracking and traceability across value chain** to meet cross-country norms
	AI-driven molecular design and R&D	**10–15 years** Time taken for new drug discovery	• **New product design and formulations (esp. for biodiversity-safe materials)** via artificial intelligence and analytics to speed up new chemical discoveries and reduce time-to-market
	Closed-loop and smart manufacturing	**75%+** equipment failures caused by design and human interface errors	• **Smart manufacturing** to use Industry 4.0 technologies for touchless automation of the end-to-end manufacturing process and predictive maintenance based on real-time sensor feedback – Real-time AI-driven process optimization: Enhancing production efficiency and reducing waste – Predictive maintenance and augmented reality (AR) training: Improving equipment uptime and worker safety – Smart factories with IoT Integration: Real-time monitoring of manufacturing processes – Closed-loop manufacturing: Recycling of chemical waste to produce new products
Long term	**Customized formulations based on customer needs**	**15M+** metric tons of hazardous waste generated in 2022–23, illustrating inefficiencies in raw material usage	• **Leveraging customer insights and requirements** to produce customized specialty chemicals – Customer insights and go-to-market strategy via AI to understand customer preferences, product launch planning, optimizing sales, pricing

Notes: GHG = greenhouse gas; IoT = Internet of Things | Sources: Secondary research; Bain analysis

Sectoral deep dives: Auto

The global automotive landscape is evolving rapidly, driven by electrification, autonomous mobility and rapid travel modes

AUTO

1 Near term (next 5 years)

Electrification and shift to EVs
EVs expected to account for over 50% of global sales by 2035 (more than 30 countries plan to phase out internal combustion engine (ICE) vehicles completely by 2035)

Reshoring and localized production
Companies prioritizing domestic production given geopolitical tensions and Covid-19 supply chain disruptions (20% reduction in component imports vs. last two years)

Shared mobility
Urbanization, limited space, and rising environmental awareness could increase use of shared mobility solutions (Potentially replace about 10 private vehicles per shared vehicle)

2 Medium term (5–15 years)

Sustainability and circularity
Countries establishing stricter sustainability standards (BMW targeting an about 40% reduction in CO_2 emissions by 2030)

Autonomous, connected vehicles
Shift from Level 3 (conditional automation, driver intervention required in specific conditions) to Level 5 (full automation with no driver intervention required in all conditions), with Level 5 to grow from ~8% (2030) to ~40% (2040+)

Personal micro-mobility
Micro-mobility solutions typically priced 50%–70% lower vs. traditional vehicles, making them attractive to price-sensitive consumers

Autonomous manufacturing
Fully automated factories integrated with emerging tech (e.g., digital twins for predictive maintenance, 3D-printed prototyping) with about 30% productivity gains

3 Long term (15+ years)

Rapid modes of travel
Magnetic levitation (e.g., Hyperloop) and pod taxis could replace current transport especially public (current use restricted to trains with speeds over 400 kmph)

Net-zero water-based fuel systems
Water-based green hydrogen vehicles to witness adoption with increased electrolysis efficiency (currently 60%–80% efficient)

Human-vehicle interfacing (HVI)
Integration of biometric sensors and AR/VR overlays could ensure high customer focus, allowing seamless control and monitoring of driver health and safety

Space-ready vehicles
Specialized vehicles with terrain adaptability and autonomous navigation for extra-terrestrial use

Notes: BOM = bill of material; AR = augmented reality; VR = virtual reality, AD = autonomous driving
Sources: Secondary research; Bain analysis

Major technology advancements could potentially transform India's automotive industry by 2047

AUTO

		Trend	Impact	Current developments around the world
Near term	**Solid State Batteries (SSB)**	Shift from traditional lithium-ion to solid-state batteries in EVs, utilizing solid electrolytes (ceramics, sulfides, or polymers) and lithium or silicon-based anodes	Increased range of EVs with fast charging (full charge in ~15 mins), ~1.5x energy density, longer life, and reduced flammability	Toyota aims to commercialize solid-state batteries by 2027–2028 and set up a BEV factory in May 2024, with target of 1.7 million vehicles by 2030
	Software Defined Vehicles (SDVs)	Software-driven systems, allowing OTA updates, AI optimizations, and cloud-based functionalities like remote diagnostics and predictive maintenance	Seamless real-time software updates provide personalized driving experience, improving vehicle adaptability and cybersecurity resilience	~3.4M SDVs were sold in 2024, with Tesla leading the market at ~50% share; Hyundai Motor Group to transition to software-defined architectures by 2025
	AR and generative AI integration	AR and generative AI integrated in dashboards/windshields to display real-time information and allow commands to answer queries/personalize experience	Intuitive, personalized support for drivers, **improving situational awareness and overall road safety**	BMW's iX models feature AR heads-up displays and are exploring generative AI integration for interactive voice commands
	Vehicle-to-everything (V2X) communication	Cars to communicate with each other, surrounding infrastructure, and pedestrians to optimize travel time and safety	Connected transportation system, **enhancing road safety and reducing congestion**	Qualcomm is testing cellular-V2X tech in Europe and the US in partnership with companies like Audi
	Autonomous vehicles (AVs)	Higher proliferation of ADAS Levels 3–5 by 2040 enabling real-time traffic optimization and increased efficiency	Easier access to safe transport**, reducing congestion, lowering emissions, limiting need for driving knowledge**	Waymo is testing fully AVs on the streets of Phoenix, Arizona, while collaborating with local governments
	Net-zero vehicles and battery systems	Vehicles to be powered using hydrogen produced from water electrolysis and emitting only water vapor as a byproduct, ensuring a carbon-neutral transportation solution	Potential to revolutionize transportation by **significantly reducing GHG emissions** and **dependence on fossil fuels**	Toyota and BMW are partnering to accelerate the development of next-generation hydrogen fuel cell vehicles, aiming for a 2028 release
Long term	**Lights-out manufacturing**	AI-driven machines/robotics to handle end-to-end complex manufacturing tasks autonomously	Zero-defect product quality, **reducing costs,** and **improving manufacturing efficiency**	Tesla's Gigafactory in Shanghai has achieved 95% automation with the use of automated robots, producing a Model Y vehicle every 30 seconds

Notes: AR = augmented reality; GHG = greenhouse gas; AV = autonomous vehicle | Sources: Secondary research; Bain analysis

To compete globally, India should consider building supportive infrastructure and leading in emerging technologies

AUTO

Key learnings from global peers

US

Significant R&D investment in emerging technologies, including ADAS and auto software

- DOE announced $200 million in funding over next five years for R&D projects focused on EV, batteries, and connected vehicles at DOE national labs and through new partnerships to support EV innovation
- The US has set up dedicated centers and programs, such as the AV TEST Initiative, to support AV R&D and allow companies to test AVs on public roads

South Korea

Significant spending to scale up charging infrastructure across the country

- The South Korean government announced a plan to install 500k EV chargers nationwide by 2025, including 12,000 fast-charging stations in high-demand urban areas, public spaces, and highways

Japan

Strengthening the upstream supply chain for auto components aimed at long-term resilience

- In 2021, Japan's Ministry of Economy, Trade, and Industry (METI) announced a $900 million fund to support domestic battery production and recycling

China

Government incentives and subsidies to gain global leadership in the EV market (58% of global market share)

- China's overall subsidies in electric mobility are 3–9x of other OECD countries (e.g., the US or Germany) (about $230 billion subsidies as sales tax exemptions, buyer rebates, funding for charging, government procurement of EVs, and R&D support provided to EV manufacturers over 2009–22)
- China established SEZs and industrial parks dedicated to battery production, offering favorable conditions (e.g., tax incentives; infra support including dedicated power grids, advanced logistics, pre-built factories; easier regulatory approvals)

Learnings for India

Continued innovation could potentially improve cost competitiveness and help gain leadership in emerging technologies vs. peers

Investing in a nationwide EV charging network with standardized, interoperable chargers might be of significance

Focus on **verticalization of the supply chain could** reduce dependency on 3P suppliers, potentially optimizing production

Leveraging government policies and infrastructure development will possibly scale up EV adoption

- Tightening Corporate Average Fuel Economy (CAFE) and emission norms could push manufacturers toward EV technology development
- Domestic EV supply chains likely to be strengthened through incentives for local production of components like batteries and motors

Notes: AV = autonomous vehicle; DOE = Department of Energy; AV TEST = Automated Vehicle Transparency and Engagement for Safe Testing; OECD = Organisation for Economic Co-operation and Development
Sources: Secondary research; Bain analysis

To grow the automotive sector, India can increase EV penetration, participation in global value chain and build a software talent hub

AUTO

Growth in vehicle ownership

- **Domestic market expected to grow 6–7x by 2047** driven by increasing vehicle ownership, accounting for $500–$600 Billion
  - 4x rise in 4-wheel ownership (currently ~50M vehicles→ ~200M vehicles in 2047) on account of rising PCI to be a key growth driver

Increasing proliferation of EVs

- **EV market at $300–$400 billion in 2047 driven by technological and infrastructure improvement**, coupled with policy support
  - EV penetration to increase significantly across 2-wheel (5% → 90%+), 3-wheel (10% → 90%+) and 4-wheel (1.5% → 75%+) ownership by 2047 inline with global trends
  - Aggressive investments by OEM's (~$4B by tata motors, Maruti Suzuki etc), lower interest rates, subsidies (~$610M under Fame-II scheme) and purchase incentives accelerate EV adoption

Greater participation in global value chain

- **Auto-components exports sector to reach $200–$250 billion (2047) driven by near-term share capture in ICE market and longer-term shift to EV**, potentially leading to larger share in global value chain
  - Several Indian companies making the last man standing play in ICE auto-comp as global players scale down production
  - Long-term growth to be driven by parallel increase in EV component exports and focused shift away from ICE as the demand slows down

India as a talent hub for auto-software

- **Advancement in the auto-software landscape with** 60+ GCCs across key hubs like Pune, Bengaluru, and Chennai; ~50% of automotive GCCs in India are from Germany and the US
- **Targeted R&D investments and partnerships with global OEMs (e.g., collaboration of BMW and Tata Technologies) to become an auto-software hub** given strong talent base and policy impetus from government
  - Investments in engineering R&D by IT services vendors like TCS, Wipro, Tata Elxsi, Tech Mahindra, etc.
  - Key OEMs (e.g., Mercedes) already investing and expanding in R&D centers in India

From (2023)	→	To (2047)	
$80B	→	$0.5–$0.6T	India domestic auto market
5%	→	90%+	India 2-wheel EV penetration
~4 GWh	→	800–850 GWh	India domestic battery demand
~$20B	→	$200–$250B	EV component exports
~$1B	→	$8–$10B	India auto software market

Notes: EV = electric vehicle; PCI = per capita income; ICE = internal combustion engine; OEM = original equipment manufacturer; GCC = global capability centers
Sources: Secondary research; Bain analysis

The automotive sector should aim to address several challenges to grow

AUTO

1 Near term (next 5 years)

Infra gaps, high costs, and raw material availability hindering seamless transition

- Charging infrastructure inadequate for population, with slow expansion in semi-urban and rural areas posing significant expansion challenges
  - Slower expansion given high upfront investment, electricity grid capacity issues and regulatory delays
  - India's grid capacity needs to expand 3x by 2040 to meet clean energy demands
- Dependence on imported raw materials (e.g., lithium for EV batteries) could increase impact of supply chain disruptions
- Higher EV costs compared to ICE vehicles hindering adoption in India's price-sensitive market

Gaps in manufacturing capabilities

- India lags against established countries (e.g., China, US) due to weaker production capabilities, esp. in EV components
- As countries focus on phasing out ICE vehicles over the next decade, limited head-room for growth of ICE exports

2 Medium term (5–15 years)

Limited R&D-led innovation leading to higher sourcing dependence

- Sub-par innovation in auto-software driven by focus on outsourcing vs. innovation
  - Substantial investment required in digital & R&D infrastructure to potentially achieve auto software leadership, transitioning from outsourcing to innovation
  - High dependence on countries for components (e.g., semiconductors, rare earth minerals) with lack of R&D to build supply chain resilience, compounding issue

Urban congestion and road infra constraints

- Insufficient road networks for the rapidly growing population constrain industry growth, as congestion discourages new car purchases
  - Commuters spend about 30 minutes to travel just 10km during rush hours in metros like Bengaluru, resulting in substantial time loss and efficiency for daily travelers

3 Long term (15+ years)

Potential demand headwinds

- Headwinds from inflation and rising interest rates, could increase costs for automakers and consumers and dampen vehicle demand
  - Elevated input costs due to inflation reduce profit margins for manufacturers, making vehicles more expensive to purchase for the end consumer

Cybersecurity and data privacy risks

- High risk of dangerous cyber attacks as software content in vehicles increases
  - In 2023, a leading Japanese car manufacturer disclosed a data breach that allowed access to location information for more than 2M customers for a decade

Notes: ICE = internal combustion engine
Sources: Secondary research; Bain analysis

Some potential levers to ensure robust growth of the Indian automotive sector

AUTO

		Current state	Potential levers
Near term	**Facilitate large-scale battery charging infra and ubiquitous charging standards**	**12k** public charging stations	• **Significant investments to scale up charging infrastructure** likely to ease range anxiety in customers – India has ~200 EVs per commercial charging point, vs ~20 in USA, <10 in China – Implementation of uniform charging standards across manufacturers and states to enhance compatibility and user convenience
	Integrate generative AI into auto software	**2%** Software content per vehicle (percentage of vehicle value)	• **Investment in building automotive software by OEMs, Tier 1s, IT services companies, etc.** to potentially improve safety and consumer experience – Tesla monetizing software-led functionalities through pilot programs – Multiple companies (e.g., Mercedes) set up and are expanding auto software R&D hubs in India—potential to become center of innovation
	Automate vehicle production factories	**25M+** vehicles manufactured in FY23	• **Scale up automotive production via set up of automated smart factories** to enhance production efficiency and reduce costs (e.g., BMW's Regensburg plant uses AI-driven monitoring and predictive maintenance to prevent ~500 minutes of annual assembly disruptions) – Strengthen EV-specific supply chains and focus on local manufacturing of critical auto parts – Autonomous factories, integrated with AI, expected to increase output by 15%–20%
	Build the V2X connectivity ecosystem	**1.4M+** connected vehicles sold in India	• **Selectively adopt V2X applications for Indian conditions** (e.g., emergency vehicle clearance, smart tolling, and driver assistance) – Tata Elxsi demonstrated V2X technology that can alert drivers about an approaching ambulance even when it is a kilometer away, allowing drivers to decongest the lane for the high-priority vehicle
	Research and adopt advanced net-zero battery tech	**35k+** tons per annum of Li-ion battery can be recycled in India	• **Consider prioritizing development of advanced battery technology (e.g., SSBs and other potential advancements in material tech like sodium-ion, graphene batteries, etc.)** to allow operation of sustainable net-zero vehicle – Encourage indigenous R&D, local battery manufacturing, enabled by domestic policies • **Implement large-scale recycling** to recover inputs (e.g., lithium), reduce import reliance, & enhance circularity – NITI Aayog projects battery recycling market growth from 2 GWh in 2023 to 128 GWh by 2030
Long term	**Investment towards ADAS L4 and L5 capabilities**	**150k+** road accident fatalities in India in 2021 (highest in the world)	• **Investments in ADAS L4/L5 suitable to Indian conditions** to improve overall safety and vehicle experience (e.g., Tata Elxsi is developing AI for object tracking over lane-based navigation) – About 94% of serious crashes are caused by human error—potential to reduce with ADAS L4/L5 capabilities

Notes: 1. AEB = automatic emergency braking; V2X = vehicle-to-everything; OEM = original equipment manufacturer | Sources: Secondary research; Bain analysis

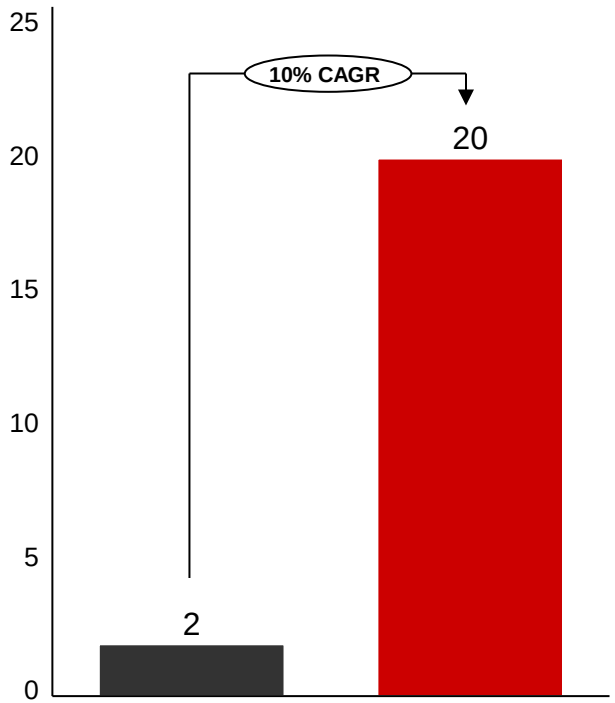
Sectoral deep dives: Services

India's services sector could contribute 60% of India's GDP by 2047, driven by key themes like favorable infrastructure, innovation, and labor advantages

SERVICES

Indian services expected to grow at about 10% CAGR to reach about $20T in 2047

India services revenue (in trillions of dollars)



Growth to be driven by favorable infra, technology, skilled workforce supply, cost competitiveness and MSME penetration

Favourable infrastructure *(tech and non-tech)*

- **Telecommunications:** Widespread adoption of high-speed internet, with over 700M 4G subscribers in India
- **India stack:** Transition to a digital economy enabled by India stack (e.g., UPI, Aadhar)
  - Digital payments in India reached $37 billion in 2020, growing at 45% CAGR from 2017
- **Urbanization:** Rapid increase in public infrastructure development
  - 100 designated smart cities being developed, with 91% of projects (worth about $17 billion) having reached completion
- **High-quality engineering & tech talent:** India produces about 1.5 million engineering graduates annually
  - Promotion of technical education across the country by establishing 90+ institutes of national importance like IIT, NIT, IISc, etc.

Tech advancement and innovation

- **India emerging as a key service provider** in cloud, AI; drivers of global transformation for global firms
  - Indian companies like TCS and Infosys specialize in cloud migration, AI applications, and custom software development
- **Growing start-up ecosystem** (third largest, more than 110 unicorns as of 2023), enabling innovation
  - Strong VC support facilitating sector growth with more than 750 start-ups raising funds in 2023, incl. 12 deals with over $100 million in funding

Availability of skilled workforce

- **Second-largest English-speaking population** (125M+), large STEM talent (second globally at 2.5M/yr.)
- **More than 1.6k GCCs set up in India** given time zone advantage and talent expertise
  - ESSCI trained more than 1.9 million people across more than 90 qualifications to attain self-reliance in electronics talent
- **Large pool of skilled professionals** at 25%–50% lower costs and in a complementary time zone to US and Europe, enabling faster project delivery
- **Stable governments and skilled talent** in India enable global companies to actively consider India for off-shoring to countries

Rising MSME contribution

- **MSMEs continue to contribute significantly to service sector growth**, fostering domestic development, providing flexible and localized job opportunities, and prioritizing inclusivity and access
  - Registered MSMEs employed about 200 million people as of 2024, adding 30% to India's GDP and 50% to exports

Notes: MSME = micro, small, and medium enterprises; GCC = global capability center; ESSCI = Electronics Sector Skills Council of India | Sources: IHS Markit; World Bank; PHD Chamber of Commerce; Nasscom; IBEF; secondary research; Bain analysis

Five technological advancements likely to disrupt India's banking, financial services, and insurance sectors

SERVICES — BFSI

near term → long term

Explainable AI-led core processing

AI helps with core banking and insurance processes (e.g., underwrites loans using real-time fraud detection to ensure risk-mitigated lending, with explainable algorithms to clarify reasoning for all parties)

Current developments around the world

Wells Fargo is developing an Explainable AI algorithm to show risk model variables to regulators and to help explain lending decisions to consumers

Virtual AI agent-led Open Banking

AI-system operating within an Open Banking framework, with agents integrating personal financial data across all financial institutions to seamlessly manage banking, insurance, and investment needs

MIT Sloan researchers are investigating potential of generative AI to deliver personalized financial advice, in understanding complex financial scenarios and to individuals with varying degrees of financial literacy

Data-based flexible insurance and claims pricing

Single point database, utilizing data from a multitude of sources (e.g., IoT, Digital Public Infrastructure, e-commerce) to enable flexible pricing and underwriting

Metromile tracks driving behavior via car sensors and smartphone apps, offering discounts on premiums depending on miles driven and safety habits of driver

Blockchain-enabled transactions

Blockchain-based financial systems that allow higher transparency, payment reliability, and accessibility while being secure

The South African Reserve Bank has piloted blockchain technology for payments, which has enabled it to speed up transaction settlement times from one day to 46 minutes

Quantum encryption for advanced cybersecurity

Use of quantum cryptography for enhanced security and faster processing in transactions involving sensitive data

US Dept. of Commerce's National Institute of Standards and Technology (NIST) has established post-quantum encryption standards to protect confidential communications

Notes: MIT = Massachusetts Institute of Technology; IoT = Internet of Things
Sources: Secondary research; Bain analysis

Some potential levers to ensure robust growth of Indian BFSI sector

SERVICES — BFSI

		Current state	Potential levers
Near term	**Embedded AI for banking/ insurance process automation**	**12.2B** UPI transactions processed in January 2024	• **Adopting AI-driven process automation at scale** could manage and fulfill significantly higher volume of daily service requests (e.g., loan applications, transaction requests, customer queries) – AI is already being used to reduce loan processing costs by more than 60%, credit decisioning time by more than 80%, and increase sales productivity by more than 50% • **Upskilling and reskilling the workforce** could ensure diligent AI model training and deployment, enabling proactive identification and mitigation of issues like model hallucination and bias
	Improved financial inclusion via generative AI	**<13%** Indians borrow from formal sources, including credit cards	• Integrating **AI-driven financial assistants** with primary lending, financial institutions, and fintech firms can enhance credit access, reduce default risks, and empower individuals and MSME – In credit risk, banks could leverage AI to accurately price risk and use patterns hidden in data to determine the likelihood customers will repay debt (or become problematic), improving its workout models, reducing problematic loans, and improving the accuracy of its provisioning
	Flexible risk-based insurance premiums	**4.0%** insurance penetration in 2023 (lower than global average of 6.8%)	• **Enable collection, build, and monitoring of user database from IoT devices and DPI interactions**, enabling provision of dynamic usage-based insurance premiums tailored to individual risk profiles – Several leading life insurance companies are integrating wearable technology, such as fitness trackers and smartwatches, to monitor policyholders' health metrics
	Peer-to-peer financial infrastructure	**80.0%** potential lower transactional costs compared to traditional methods	• **Integrating blockchain-based infrastructure into financial services ecosystem** could potentially offer greater transparency and accessibility for Indian users – Platforms like NPCI's "Falcon" and private initiatives like Polygon-based fintech solutions could be used to integrate blockchain into India's financial infrastructure
Long term	**Enhanced cybersecurity and data privacy**	**140M+** cyberattacks faced by India in February 2023	• **Strengthening data protection frameworks and protocols** could secure high volume and frequency of digital data transmissions and transactions while enabling live fraud detection – Potential for use of advanced quantum encryption techniques to protect against attacks involving high-computing power

Notes: DeFi = decentralized finance; IoT = Internet of Things; DPI = digital public interactions, NPCI = National Payments Corporation of India | Sources: Secondary research; Bain analysis

Five technological advancements likely to disrupt the India's retail sector

SERVICES — RETAIL

Near term → **Long term**

Hyper-personalized shopping with generative AI, AR	Blockchain-led supply chains	Autonomous delivery drones and robots	Rapid mind-to-market delivery	IoT-based autonomous store management
Use of extended reality (XR) and AI assistants could offer personalized suggestions and immersive ordering (e.g., digital walls as stores) and virtual product try-ons	Transparent blockchain records could enable consumers and distributors verify authenticity of products and track shipments	Last-mile delivery and warehouse management likely to be fastened by autonomous drones and robots, esp. in remote locations	Use of tech-enabled manufacturing processes (e.g., 3D printing, digital garment knitting, virtual product simulations) could allow rapid product launches	Touchless store where customers find items via app, with store billing and inventory mgmt. (e.g., automated replenishments) via IoT could emerge

Current developments around the world

In 2023, European fashion retailer Zalando launched a ChatGPT-powered assistant that provides personalized fashion advice and recommendations	Walmart uses IBM's Food Trust blockchain to track produce from farms to shelves, enhancing transparency, efficiency, and food safety in its supply chain	Amazon Prime Air is piloting use of drones for last-mile e-commerce deliveries across a limited number of cities in the US, UK, and Italy	Israeli company MeaTech 3D is developing lab-grown steaks by layering 3D-printed cells that mature into fat and muscle, replicating the texture and composition of traditional meat	Amazon Go is a pilot cashier-less store that uses AI, computer vision, and sensor tech to enable customers to have product charges applied directly to their Amazon account

Notes: AR = augmented reality; IoT = Internet of Things
Sources: Secondary research; Bain analysis

Some potential levers imperatives to ensure robust growth of the Indian retail sector

SERVICES — RETAIL

		Current state	Potential levers
Near term	**Personalize shopping experience**	**25%–40%** return rate for online clothes	• **Building AR-based virtual shopping technology** could enhance customer experience and reduce returns given greater confidence while buying products (e.g., clothing, furniture) – More than 90% Americans currently use or would consider using AR for shopping, with over 98% finding it helpful
		15B hours spent on hold by Indians in 2023, costing businesses $55B+	• **Deploying generative AI-based virtual assistants** could scale automated conversational commerce, helping customers with any queries and suggesting hyper-personalized products using past customer data – 66% of Indian brands regularly use generative AI and almost seven in ten believe the need is immediate
	Leverage blockchain in supply chain	**13%** of GDP spent on logistics costs in India in 2020 vs. global 8%	• **Integrating blockchain technology could potentially track and record supply chain data**, enhancing transparency and authenticity for customers and distributors, while building trust with kiranas and local shops – Indian consumers showing a strong preference for brands with ethical manufacturing processes
	Allow autonomous drone-based delivery	**53%** of shipping costs incurred in last-mile logistics	• **Introduce last-mile drone delivery in urban and rural areas**, with special focus on remote locations with restricted logistics infrastructure – Government to enforce clear drone regulations and air traffic control standards to ensure safety of operations
	Integrate on-demand prod. into supply chain	**15%–25%** longer lead time than Chinese fabrics and apparel players	• **Incorporating tech-enabled manufacturing systems into supply chains** could enable rapid production of consumer goods as per demand, reducing lead times and minimizing inventory costs – 3D printing has been shown to reduce lead times by up to 97% for production of commoditized goods
Long term	**Automate physical stores using IoT**	**1.6%** shrink rate (due to theft and inventory error) globally in 2022; rising rates for Indian retailers	• **Integrating IoT systems in physical stores** could automate customer journey operations (e.g., automatic inventory replenishment), enabling kiranas to offer seamless shopping experiences – Automated inventory management reduces manual entry errors by up to 90%, with companies integrating IoT into their inventory management systems seeing a 15% reduction in logistics expenditure

Notes: AR = augmented reality; IoT = Internet of Things | Sources: Secondary research; Bain analysis

Five technological advancements likely to disrupt India's healthcare sector

SERVICES — HEALTHCARE

Near term → **Long term**

Wearable and implantable health monitoring devices	AI-based predictive healthcare mechanisms	Immersive telepresence treatment	Precision medicine leveraging genomics and biomaterials	Nanotechnology and brain-computer interfaces
Using wearable and implantable devices could continuously monitor health data and provide proactive care	Systems that use past patient data and healthcare databases to predict disease risk and suggest preventive measures could come up	Surgeons potentially operating virtually using high-precision robots and 3D VR/AR environments	Targeted, personalized care to each patient via genomics-based analytics and bio-inspired custom nanomaterials (including 3D printed tissues and drugs)	Enable drug delivery, enhanced prosthetic control, and seamless integration with human neural network

Current developments around the world

Dexcom G7 is a continuous glucose monitoring wearable sensor that provides real-time readings and alerts for people with diabetes, allowing for improved glucose mgmt.	Google's DeepMind has developed an AI system using deep learning to accurately detect diabetic retinopathy and macular edema from retinal scans, matching the diagnostic ability of human physicians	Intuitive Surgical and Osso VR are advancing robotic-assisted and VR/AR-supported surgical technologies respectively, enabling minimally invasive surgeries and virtual collaboration	Genomics England is a government-backed initiative that has sequenced 100k genomes to improve the diagnosis and treatment of genetic disorders	Neuralink is developing brain-computer interfaces that aim to restore mobility for paralyzed patients and enable control of devices through thought

Notes: AR = augmented reality; VR = virtual reality
Sources: Secondary research; Bain analysis

Some potential levers to ensure robust growth of the Indian healthcare sector

SERVICES — HEALTHCARE

		Current state	Potential levers
Near term	**Introduce cutting-edge equipment and infra**	**1.5–2** MRI machines per million people, compared to 10–30 for developed nations	• **Modernizing healthcare infrastructure** by investing in up-to-date equipment and infrastructure could improve overall care quality – Especially necessary in rural and underserved areas, where infrastructure fails to meet even basic requirements
	Leverage AI for predictive healthcare	**60%** deaths in India caused by chronic illnesses	• **Use AI to predict diseases and manage treatments** potentially helping with early diagnosis and easing hospital burdens in the long term – India faces a shortage of 600,000 doctors and 2 million nurses, with people dying of treatable diseases due to lack of access to information and care
	Foster inclusivity by expanding remote care	**65%+** Indians live in rural areas with limited access to healthcare	• **Expanding access to healthcare via remote and telemedicine services** could ensure equitable access by reaching low-access areas – eSanjeevani, India's national telemedicine service introduced by the Union Health Ministry, has crossed 30 million tele-consultations as of 2022
	Integrate genomics into precision medicine	**19** Registered biobanks out of 340 globally (about 95% in North America and Europe)	• **Integrating genomics and precision treatments into regular care** could enable personalized treatments and hasten drug discovery, specifically for cancer and genetic diseases – Post approval of immunotherapy drugs for metastatic melanoma in the US, overall death rate dropped 7% annually from 2013 to 2017 for patients aged 20 to 64
Long term	**Adopt emerging technologies for disability care**	**26.8M** people living with disabilities as per the 2011 census	• **Use new technologies (e.g., nanotech, regenerative medicine, brain-computer interfacing) to develop innovative treatments** for chronic conditions, injuries, and disabilities potentially reducing long-term costs and improving quality of life – Stentrode is a minimally invasive brain-computer interface implanted via blood vessels that allows patients to control digital devices through thought, achieving up to 92% accuracy in tasks like texting within 3 months of use

Sources: Secondary research; Bain analysis

Future state of tech services likely to be affected by AI, deglobalization, new workforce dynamics, and evolving regulations

SERVICES—TECH SERVICES

Tech disruptions (AI/ML, DLT, etc.)

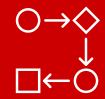
Accelerating global AI adoption, esp. at edge and **AI-led transformation across use cases**, enabling firms to leverage automation and potentially reducing cost

Deglobalization and evolving service model

Growing protectionism led by geopolitical instability to **limit services exports** and entail movement from GCCs to the **emergence of integrated service delivery models**

Evolving workforce dynamics

Moderated incoming tech talent (new career options with Gen Z) warrant interventions to capture the demographic dividend and potentially boost productivity



Staying abreast with regulations

Rapidly evolving global and domestic regulations could help foster data security and control of emerging tech

Implications going forward

- Customized AI-driven processes and agents could **enhance efficiency and transform service delivery**
  - Generative AI estimated to replace 300M redundant jobs, esp. in US and Europe, increase global GDP by $7T due to improved labor productivity
- Increasing AI demand across client industries **could potentially drive the need for new skills in AI landscape**
  - Indian AI talent demand expected to double from 0.6M in 2024 to more than 1.25M by 2027

- Opportunity **to diversify tech services offerings** while strengthening domestic capabilities
  - Tech services exports accounted for about 85% of overall revenue in 2023
- **Boosting innovation in high value-added services** and global partnerships could help sustain India's tech export edge (e.g., ER&D)

- Opportunity to enhance **workforce productivity** and revenue generation potential
  - e.g., US IT workforce productivity about 17x of India
- Optimize workforce with **usage of automation and IoT** to align with evolving market demand

- Increased compliance costs for firms **could hinder innovation and technology sharing**
  - Studies estimate a cost of about $1.7 million for GDPR compliance for a small and mid-sized company
- **Streamline regulations, risk-based compliances and usage of RegTech** to create regulatory sandboxes and potentially enable technology sharing

India has a significant opportunity to drive sustained growth in the sector by building resilience through proactive measures and embracing emerging technologies

Notes: GCC = global capability centers; IoT = Internet of Things; GDPR - EU's General Data Protection Regulation; ER&D = engineering, research, and development | Source: Secondary research; Nasscom

Five technological advancements likely to disrupt India’s tech services sector

SERVICES—TECH SERVICES

Near term → **Long term**

AI/machine learning (ML) everywhere	Distributed ledger technology (DLT)	Zero-touch IT services operations	Quantum and high-performance technology	Human-machine integrated ways of working
Use of AI/ML could lower costs and unlock potential for newer use cases across the value chain, from design to deployment to testing and after-sales service	Decentralized systems (e.g., blockchain) securely manage data across nodes, enabling use possible cases (e.g., identity management)	Autonomous IT service model that uses self-healing tech to manage and resolve IT ops with minimal/no human intervention	Quantum and high-performance computers to process complex data in real-time at very high speeds are upcoming	Combination of AI agents, metaverse, and immersive experiences allow all ops. without need for physical presence

Current developments around the world

In Jan 2025, DeepSeek advanced AI efficiency by using selective processing to reduce energy use and enhance performance. Additionally, smarter memory mgmt. cut storage needs by 75%, making AI faster and accessible on everyday devices	DLT projected to reach $103.15 billion market (2030, 62.55% CAGR) and is driving cost reductions, fraud prevention, and real-time transformation in financial services and supply chains	The global zero-touch provisioning market is projected to reach $~6 billion by 2030, as enterprises reduce setup time by 50% and cut IT support costs by 70% through automated device deployment	Google's 105-qubit quantum processor, "Willow," completed a computation in less than five minutes that would take the fastest supercomputers approximately 10 septillion years	Meta’s total cumulative investment in virtual and augmented reality has exceeded $80 billion to date

Potential levers to ensure robust growth of Indian tech services sector

SERVICES—TECH SERVICES

		Current state	Potential levers
Near term	**Develop expertise in AI and ML (incl. generative AI and adv. algorithms)**	**71%** dip in funding for Indian AI start-ups from 2022 to 2023	• **Deploy AI and machine learning at scale across use cases** with contextualized training data to best suit Indian use cases, including development of sovereign generative AI models – The government has approved an about $1.2 billion investment for the national level India AI Mission to develop homegrown foundational models
	Build resilience against de-globalization	**25%** new data center capacity to come from local providers by 2027	• **Developing expertise and targeting future markets** could sustain sector growth despite localization policies – Building capabilities in emerging technologies like AI, blockchain, and quantum tech could help in expanding beyond traditional outsourcing and transforming GCCs into innovation hubs – Prioritizing emerging economies (e.g., SEA, Africa) in addition to the growing domestic market could support future growth
	Automate IT-ops leveraging DLT across systems	**<0.3%** IT professionals skilled in blockchain tech as of 2022	• **Implementing DLT across systems** could ensure more secure and transparent workflows – India's blockchain-based digital e-rupee has about 5M users and is accepted by more than 400k businesses as of 2024
	Invest in quantum tech research and deployment	**<5%** India's share in global quantum tech R&D	• **Encouraging research in quantum and high-performance technology** could enable high-speed and high-volume data processing capabilities – In 2023, GoI approved National Quantum mission with about $1B funding and target of building 20–50 qubits of computing
Long term	**Enable digital integration for future ways of working**	**74%** Indian workers keen on flexible remote working options as 73% are looking for in-person collaboration	• **Adopting wide-spread use of AR and VR** for virtual workspaces and immersive training environments could offer greater flexibility to tech services employees while maintaining in-person collaboration – Employees undergoing VR training programs demonstrated up to 75% higher engagement rate compared to traditional training modules

Notes: DLT = distributed ledger technology; GCC = global capability center; SEA = Southeast Asia; GoI = Government of India; VR = virtual reality | Sources: Nasscom; Secondary research; Bain analysis

Five technological advancements likely to disrupt India’s telecom sector

SERVICES — TELECOM

Near term → **Long term**

Edge computing for low latency applications	Cloud-native software defined networks	6G and beyond	Advanced materials	Quantum network optimization
Localized data processing through edge computing could potentially significantly reduce latency and bandwidth demands	Cloud-native network functions virtualization and software-defined networking architecture will make networks more flexible and scalable	Next generation of wireless networks will leverage terahertz (THz) frequencies and LEO satellites to deliver ultra-fast data speeds and lower-latency	Materials (e.g., graphene, metamaterials) will boost signal efficiency, enable faster connectivity and lower power use	Quantum computers likely to solve network optimization problems (e.g., traffic routing, load balancing efficiently vs. classical methods)

Current developments around the world

Verizon's 5G Edge platform integrates computing and storage at network edge or on-premises, enabling low-latency applications	Cisco is integrating cloud-native NFV solutions into its SDN portfolio, helping telecom operators achieve scalable, programmable networks	Samsung Electronics has demonstrated a 6G THz wireless communication prototype and its application for future wireless communications	Beginning Feb 2024, Flawless Photonics is piloting ZBLAN optical fiber manufacturing on ISS, using microgravity to achieve significantly lower signal loss vs. silica fibers	IBM and Vodafone are partnering to explore quantum computing use cases across Vodafone’s infra (e.g., quantum-safe cryptography to protect data, systems)

Notes: NFV = network functions visualization; SDN = software-defined networking; ZBLAN = zirconium, barium, lanthanum, aluminum, sodium; LEO = low Earth orbit

Some potential levers to ensure robust growth of the Indian telecom sector

SERVICES

		Current state	Potential levers
Near term	**Optical fiber infra expansion and last-mile connectivity**	**84th** rank in average fixed broadband speed	• **Expanding and upgrading fiber connectivity across the country** could improve access to faster-fixed broadband connections – Improved fiber deployment could further enhance rural access to digital services, such as education and telemedicine, as only 29% of rural India had internet access as of 2022 – Utilizing next-gen materials (e.g., graphene, photonic crystals) and nanotechnology-based research could further increase data transmission speed and efficiency
	Robust network planning and optimization architecture	**24.1GB/month** avg. mobile data usage per user	• **Implementing the latest network planning techniques** (including AI and quantum tech) could optimize internet access for the huge user base in India – Studies show that 56% of users report connection disruptions and lower speeds than they paid for even as companies like Airtel and Jio have pledged to spend about $9 billion to fortify their infrastructure
	Network virtualization	**25%–30%** of revenue spent in opex costs	• **Transitioning from legacy to cloud-based networks** could reduce hardware maintenance costs while enhancing system flexibility and scalability – Studies indicate that network operators who fully virtualize their networks can achieve up to 44% in total cost of ownership (TCO) savings
	6G development and adoption	**133%** teledensity[1] in urban areas, with need for optimized connectivity standards	• **Positioning India as a global 6G and LEO R&D hub** could ensure faster deployment and adoption across sectors – 6G is expected to enable real-time latency below 1ms, crucial for applications like autonomous drones and smart factories – Accelerating 6G innovation, the Department of Telecommunications (DoT) has approved 111 proposals under the Accelerated Research for 6G Ecosystem initiative, with ~$27 million allocated for a 6G testbed to potentially drive research, start-ups, and industrial collaboration
Long term	**Integration of satellite communication**	**65%** of population lives in rural areas with inadequate connectivity	• **Deploying satellites could ensure uninterrupted connectivity in remote and hard-to-reach areas** and could effectively address connectivity gaps and support critical communication needs – Implementing satellite-based internet can provide reliable communication during disasters, enhancing resilience for individuals in vulnerable areas (e.g., about 59% of India's landmass is prone to earthquakes of moderate to very high intensity)

Notes: 1. Defined as the number of telephones per 100 people; LEO = low-earth orbit | Sources: Nasscom; secondary research; Bain analysis

The services sector should aim to address several challenges to grow

SERVICES

1 Near term (next 5 years)

Lack of access to digital infrastructure

- Access to reliable internet and network a challenge for rural India (29% penetration in rural households)
  - India needs to rapidly scale up infrastructure to meet needs of growing population

Privacy and cybersecurity

- Lack of a comprehensive data protection framework despite large volume of data generated
  - Concerns over data misuse and inadequate user consent mechanisms
- Difficulty in managing data privacy across borders esp. for multiple MNCs operating in and outsourcing to India

Technology capacity bottlenecks

- Lack of tech infra/capacity needed to support the scaled adoption of tech in services sector
  - India has 3% of the global data center capacity, signaling the need for significant investment

Regulatory complexities

- Difficulties in complying with rapidly changing global and domestic regulations as governments protect against emerging tech
  - Indian banks face challenges balancing GDPR[1] compliance with DPDP Act[2] mandates—cross-border and localization rules heighten complexity and costs

2 Medium term (5–15 years)

Concentrated services exports

- India's export end-market highly concentrated (about 80% IT software and services revenue from US and UK), with diversification necessary to de-risk and expand further

Reduced talent ROI

- Rising labor and operational costs especially for high-demand skills outpacing productivity gains, could lead to higher costs relative to revenue

3 Long term (15+ years)

Need for innovation leadership

- India leads globally in services outsourcing (more than 55% global share for tech services), but lags in product development and innovation (about 5% share in SaaS market)

Declining shelf life of skills

- Rapid technological advancements require continuous reskilling, but availability of skilled workers lags industry demand
  - More than 80% of employers reported difficulties in finding skilled manpower (about 87% for IT sector)
  - Need for educational op model shift to enable accelerated skill refresh as per industry requirements
- As reliance on AI increases, human expertise could potentially decline
  - Major problem arising from AI dependence on historical data, curbing revolutionary future innovation

Notes: 1. GDPR = EU's General Data Protection Regulation; 2. DPDP Act = India's Digital Personal Data Protection Act; MNC = multi-national company
Sources: Secondary research; Bain Analysis

Focus areas

Transformative technologies are reshaping multiple sectors

Established themes

- Cloud computing
- Big data
- DevOps
- Integrated payments
- Automation and robotics
- Mobile technologies
- Traditional BPO services

Emerging over the near term

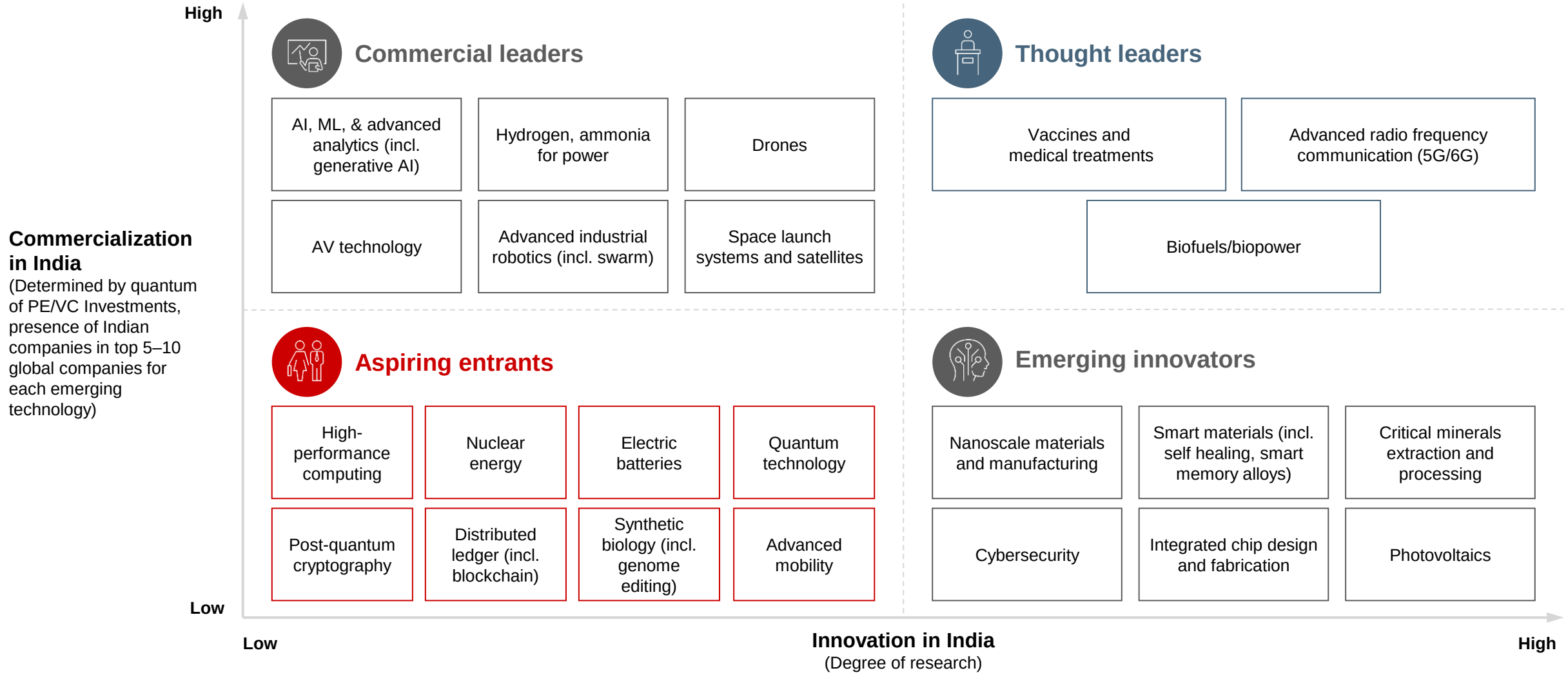
- 5G roll-out
- Citizen developer low code/no code
- Blockchain and crypto
- Internet of Things
- Cybersecurity
- Autonomous driving/ADAS
- AR/VR
- Wearables
- AI/ML/ generative AI

Future innovation drivers

- Quantum technology
- Advanced nuclear technologies
- HMI and neuromorphic chip design
- Autonomous drones and robots
- Next-gen rapid modes of transport
- Smart materials
- 6G & Satellite Comms.

Notes: BPO = business process outsourcing; ML = Machine Learning; ADAS = advanced driver assistance systems; HMI = human-machine interfacing

India is making strides in select emerging themes, but there are significant opportunities for India to innovate and monetize technology



Notes: ML = Machine learning; AV = autonomous vehicle | Sources: ASPI report; market participant conversations; secondary research; Bain analysis

The US and China have used government-private sector collaboration to pursue emerging technologies

Archetype	Technology	Leader	Learnings: Differentiated effort to build leadership
Emerging Innovators	**Critical minerals extraction & processing**	**China**	• **Government investment in resource processing capabilities which could augment natural reserves and their final usable forms** – Processes 99% of world's battery-grade graphite and refines 80% of magnet rare earths, while holding only 80% graphite, 60% of magnet rare earth • **Cross-country strategic partnerships which could help in securing raw materials from countries with rich deposits** – Chinese firms control about 40% of Indonesia's nickel production (Indonesia accounts for half of the world's nickel reserves) – China invested around $11 billion to acquire mines across Africa in 2023 to secure minerals to ensure its leadership across industries (e.g., EV, semiconductor)
Commercial Leaders	**Space launch systems and satellites**	**US**	• **Strategic government focus, necessitated by geopolitical strategy could ensure leadership in space exploration/innovation** – NASA received funding of $25 billion from the US government in 2023 – NASA commissioned multiple missions (e.g., Psyche) to test high-bandwidth communications in deep space and allow for faster/complex data transfer • **Private sector-led innovation could commercialize space exploration** – SpaceX accounts for about 43% of all global launch attempts in 2023 – US contributes more than 2.9k satellites in orbit, far ahead of all global peers, driven by companies (e.g., SpaceX, Virgin Galactic)
Aspiring Entrants	**Quantum technology**	**US**	• **Government investments and policies could aid research and attain global innovation leadership** – National Quantum Initiative Act, signed in 2018, outlines a detailed plan to further quantum technology and offers support for government agencies to develop programs related to quantum science and technology – US DOE announced $65 million investment in quantum tech research, primarily targeting software, control systems, and algorithmic advancements • **Private sector-led innovation could be supported by existing software leaders and new start-ups** – Leading companies like IBM, Google, and Microsoft are investing heavily in quantum tech, with Google's AI division having created a 53-qubit superconducting quantum processor – More than 130 quantum tech-focused start-ups in the US in 2024

Note: DOE = Department of Energy
Sources: Secondary research; Bain analysis

Viksit Bharat 2047 envisions a stronger and more dominant India

India of 2047 to look very different from today:

A high-income developed economy with **GDP of ~$23–$35T**

Current state 2023	Target state 2047
$3.6T GDP **Fifth-largest economy**	**~$23–$35T GDP** **Top three global economy**
$2.5k PCI **Low-income, developing nation**	**$15–$20k PCI** **High-income, developed nation**
500–550M workers — **29%** female LFPR	**700–750M** workers — **40%–50%** female LFPR
Low skilled, male-dominant workforce	**Highly skilled, diverse workforce**
Electronics imports **3x** of exports — **Chemicals** imports **2x** of exports	**45%** for electronics — **35%–40%** for chemicals (Net exporter across major sectors)
Primarily import-driven nation	**Export-driven nation focused on GVC**
23% 5G penetration driving → **~50%** internet penetration	**90%+ 5G** penetration driving → **95%+** internet penetration
Inadequate infrastructure, focused only on urban India	**Tech-enabled infrastructure, across rural and urban India**
Service-led technology leader (Enabled via standardized, outsourced technology services)	**Products-led technology leader** (Enabled via quantum technology, AI, smart materials, digitalized mfg.)

Notes: PCI = per capita income; LFPR = labor force participation rate; GVC = global value chain
Sources: CEIC; IMF; ILO; UN population statistics; Bain analysis

Several focus areas for the government to achieve Viksit Bharat 2047 (1/3)

India strategic leadership

Mission mode governance

- **Central task force:** Establishing a task force for Viksit Bharat@2047 reporting directly to the Prime Minister's Office which could help in coordinating sectoral growth strategies, policies, and investments
- **Sectoral master plans:** Support development of detailed five-year action plans for priority sectors (e.g., electronics, energy) which could include measurable milestones and accountability mechanisms for ministries
- **State-federal coordination:** Set up state-level economic councils aligned with the central vision which could be incentivized through performance-linked funding for achieving industrial and export growth

Global innovator build-up

National Champion Strategy

- Identify and promote domestic firms in strategic sectors (e.g., AI, semiconductors, green energy, EV manufacturing) potentially encouraging the structural transformation toward skill intensive and higher productivity sectors
- Support scale-up funding for global competitiveness using measures that could include low-cost credit, export subsidies, tech blueprinting and adoption (e.g., Türkiye's $30 billion High-Technology Investment Program)

SME market access

- Set a SME Export Platform which could integrate SMBs into global supply chains and provide them with trade finance

Sectoral nourishment

ELECTRONICS: Focused incentivization

- PLI scheme could be expanded to include emerging areas (e.g., wearables, Internet of Things)
- Providing tiered incentives for local component manufacturing could reduce import dependency

ENERGY: Renewable energy build-up

- Expanding National Green Energy Mission beyond hydrogen could promote battery storage, and solar panel manufacturing
- Mandating RE adoption for large industries with targeted subsidies could lead to early compliance

AUTOMOBILE: EV infrastructure development

- Establishing a National EV Ecosystem Fund could develop local EV manufacturing clusters and charging infrastructure
- Incentivize recycling and reuse of EV batteries through measures which could include tax rebates and R&D grants

CHEMICALS: Manufacturing sustainability

- Incentivizing adherence to global environmental standards could position India as a leader in sustainable chemical manufacturing
- Specialty chemicals and bio-based chemicals production could be provided with long-term tax holidays

SERVICES: Diversification

- Development of high-value service clusters in Tier 2/3 cities could be supported with training and infrastructure subsidies
- Export incentives could be extended for IT, AI, and digital services, especially targeting underserved regions like Latin America and Africa

Notes: SME = small and medium enterprise, SMB = small and midsize business, RE = renewable energy, PLI = production-linked incentive

Several potential focus areas for the government to achieve Viksit Bharat 2047 (2/3)

Global competitiveness

Infrastructure development

- **Export-oriented infrastructure**
  - Supporting the development of integrated manufacturing and clusters/export hubs with plug-and-play facilities for industries like electronics, EVs, chemicals could be important
  - Modernizing logistics systems via initiatives like multi-modal connectivity corridors linking ports, airports, and industrial parks could be relevant
- **Urban-rural linkage**
  - Introducing potential “growth rings” around major cities could develop rural industries connected to urban markets (e.g., agri-processing near metropolitan areas)
- **Energy sustainability**
  - Creating green energy zones could allow uninterrupted renewable power supply for key industries
  - Investing in a robust national grid for potentially improved reliability in electricity supply in rural and industrial areas

Trade partnerships

- **India-centric agreements**
  - Potentially pursuing free trade agreements with global groups like ASEAN, Africa, the EU, and the US could lead to tariff reductions in strategic sectors like green energy, electronics, specialty chemicals
  - Potentially simplifying tariff structures to support access for raw materials critical to industries like chemicals, electronics, and EV manufacturing
  - Clearly articulating the long-term trade policy with neighboring countries like China (incl. foreign direct investment raw material sourcing agreements), could specify sectors for restrictions to help manufacturers build alternative value chains
- **Export diversification**
  - Potentially creating government-led trade delegations and export promotion initiatives to potentially target emerging markets in Africa, Latin America, and Southeast Asia
  - Potentially securing preferential trade terms which would cover India's high-value services and digital exports
- **Trade digitization**
  - Potentially digitizing customs systems to target 24/7 clearance for exports and imports

Several potential focus areas for the government to achieve Viksit Bharat 2047 (3/3)

Domestic enablement and resilience

Workforce employment

- **Future skills training and increasing workforce participation**
  - Launch a National Skill 2047 Mission that could train 200 million workers in key areas (e.g., EV maintenance, AI across verticals, software development)
  - Potentially partnering with private players to potentially expand skill training in emerging tech
  - Increase participation of women in the workforce by providing access to modern needs like mobility, soft skills training, and loans
  - Empower the workforce with access to facilities like healthcare and finance, which could enhance reach by using technology with “for India” solutions (e.g., microfinancing, telehealth)
  - Support the creation of future-ready workforce by possibly embedding school-level training and curriculum enhancement
- **Reverse brain drain**
  - Potentially creating incentives for Indian diaspora professionals to return/prevent movement which could include tax benefits, housing support, and research grants
- **Entrepreneurship enablement**
  - Scale up financial and mentoring support for rural and semi-urban entrepreneurs through schemes like the District Entrepreneurship Program
  - Develop programs that could integrate women, underrepresented communities into the workforce
  - Promote funding and enablement of deep-tech start-ups to potentially improve technical entrepreneurship

Technology transfer

- **Global collaboration**
  - Potentially developing partnerships with leading nations for potential knowledge and tech transfer in critical sectors (e.g., AI, semiconductors, renewable energy)
  - Potentially secure access to rare earth materials via strategic alliances with peers (e.g., Australia, Chile)
- **Domestic manufacturing and infrastructure support**
  - Potentially incentivizing the local production of goods like semiconductors, EV batteries, and advanced chemical inputs via measures that could include targeted subsidies and infrastructure support
  - Extend build of public infra & citizen services (like DPI, Aadhar) to potentially bridge the digital divide

Research-led innovation

- **National R&D Investment Fund**
  - Potentially allocating a higher share of GDP for R&D (potentially closer to 3%, with a potential focus on strategic sectors such as semiconductors, green energy, and quantum tech (vs. less than 1% today)
  - Establishing dedicated R&D hubs which could promote chemical innovations and advanced materials should be considered
- **Public-Private R&D Partnerships**
  - Potentially incentivizing private sector participation in national research projects with initiatives that could include co-funding agreements and IP-sharing agreements
- **Technology Adaptation**
  - Promote the adaptation of imported technologies to Indian conditions, possibly in agriculture, EVs, and renewable energy

Decentralized innovation

- **Regional specialization**
  - Encourage states to specialize in sectors based on their comparative advantage (e.g., Karnataka for AI and IT, Gujarat for chemicals, Tamil Nadu for EVs)
  - Potentially introducing a competitive federalism index that could rank states on industrial output, innovation, and inclusivity with the aim of fostering healthy competition
  - Potentially using a performance-based federal support fund could potentially incentivize and reward states for achieving industrial and export milestones
- **Localized investments**
  - Potentially allowing states greater autonomy such that they could set localized industrial policies while aligning with national goals might be beneficial
  - Potentially expanding One District, One Product (ODOP) by potentially connecting rural industries with national and global markets via e-commerce platforms

Companies can pursue four imperatives to help India achieve its 2047 vision

Future-back strategy

- **Continuous evolution of business model** to incorporate future trends
  - Embed sustainability across value chain to potentially drive positive consumer association
  - Potentially leapfrog global competitors with legacy systems through emerging tech
  - e.g., XaaS models in tech services, Smart factory models in manufacturing industries, Phy-gital models in retail

Technology-led transformation

- **Reconfigure value chain to be a technology- oriented network** across end-to-end supply and production customer/sales systems
  - e.g., leverage AI-led digital twin systems to enable predictive maintenance and advanced materials to improve performance

Digital infrastructure

- Invest in **building foundational layer for seamless integration** of latest technology, manufacturing systems and labor
  - e.g., deploy latest IT/operational technology systems on factory floor to capture data in real time

Skilled labor and agile operating model

- **Build new structure, roles, skills and capabilities across organization** via rapid upskilling
  - e.g., provide online courses and industry collaborations that could keep the workforce relevant and competitive on a global scale
- Support the shift from rigid hierarchies to **flexible, multidisciplinary agile** teams to possibly bolster high performance

Sources: CEIC; IMF; ILO; UN population statistics; Bain analysis

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