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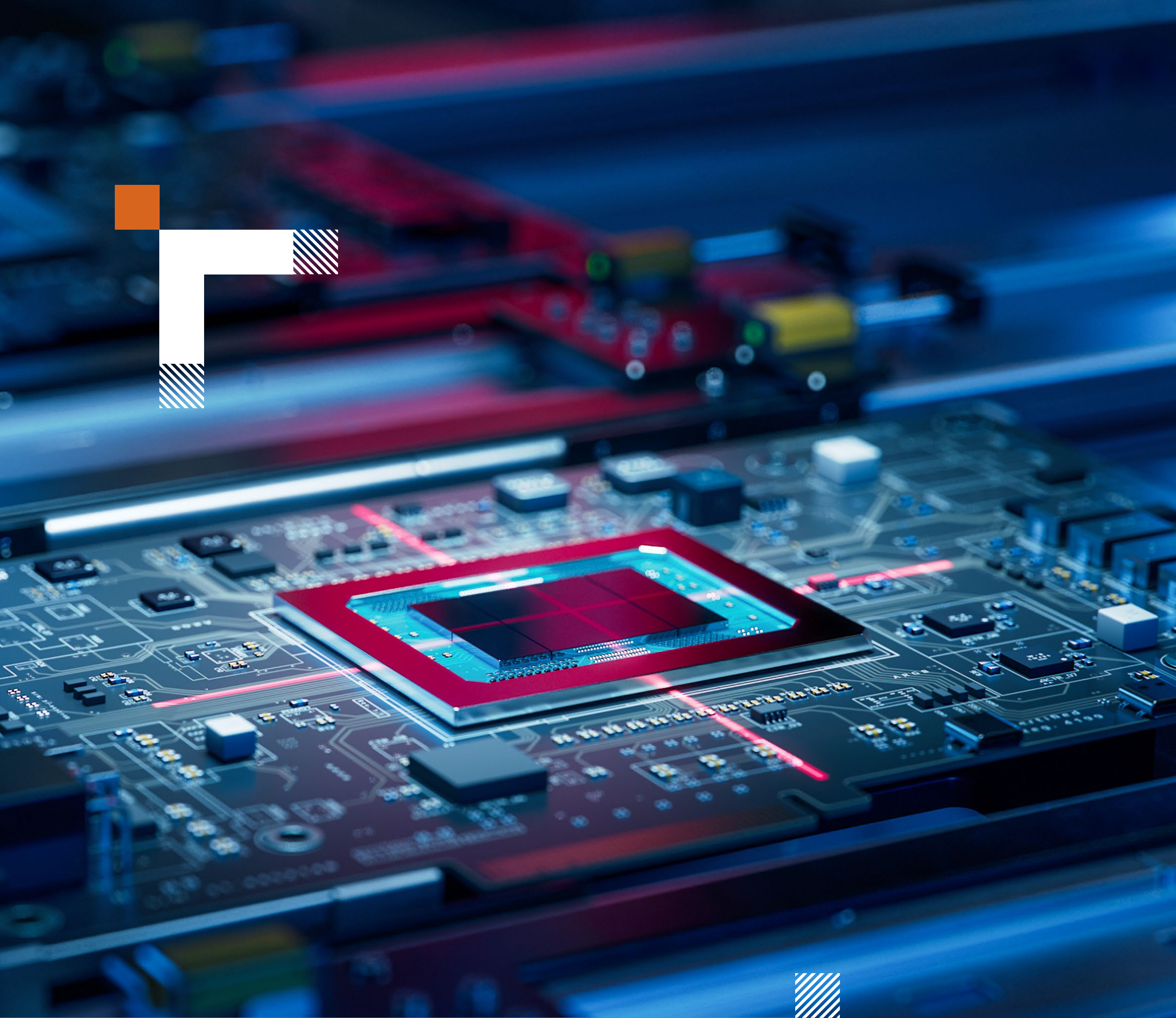

# The India opportunity: Developing resilient electronics supply chains

pwc

ORF OBSERVER RESEARCH FOUNDATION

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# Executive summary

Recent geopolitical realignments have created a state of uncertainty in the global economy. Supply chain disruptions, which began with the COVID-19 pandemic, have worsened following the conflict in Ukraine and are threatening global economic security. Further, the US-China trade conflict has highlighted the vulnerability of the global economy due to overreliance on a small number of countries for the supply of critical raw materials, components, and products across sectors. The politics of high-technology trade, which has led to recent export curbs by China, are also a part of this continued uncertainty.

This report discusses the role of the ESDM sector in India as it is not only a strategic sector but also the sector with tremendous growth potential. India's ability to produce for the global market has been showcased primarily in four key electronics sectors – mobile phones, consumer electronics, IT hardware, and electronic components – comprising more than 70% of India's domestic manufacturing landscape.[1] From 2015 to 2022, mobile phone production has surged from 60 million to 310 million at an impressive CAGR of 26%.[2] India's development of its smartphone production systems has been a good case-study to witness how nations can catalyse manufacturing system through clear policy objectives. However, to ensure that this growth momentum is further boosted for building resilient supply chains, it is important that India takes strides to seamlessly integrate its production into global supply chains. This will entail initiating policy reforms which encourage global lead firms to invest in the country as well as enable domestic companies to be part of the global value chains.

The COVID-19 pandemic drove home two important points for the global economy:

(i) the need to minimise dependence on a single source for critical goods, and

(ii) the importance of fostering intra-regional and domestic self-sufficiency in value chains.

This realisation is also a key factor behind the China+1 strategy which several countries have adopted.

Additionally, the increase in the cost of labour in China has created opportunities for countries like India, which already possess a skilled workforce and are cost competitive. The Indian Government has been actively creating policies to attract leading firms in the value chains to set up production operations in India. Addressing issues related to inverted tariff structures, rationalising state-level tax regimes and incentive schemes have all been a part of India's recent industrial and foreign policy basket.

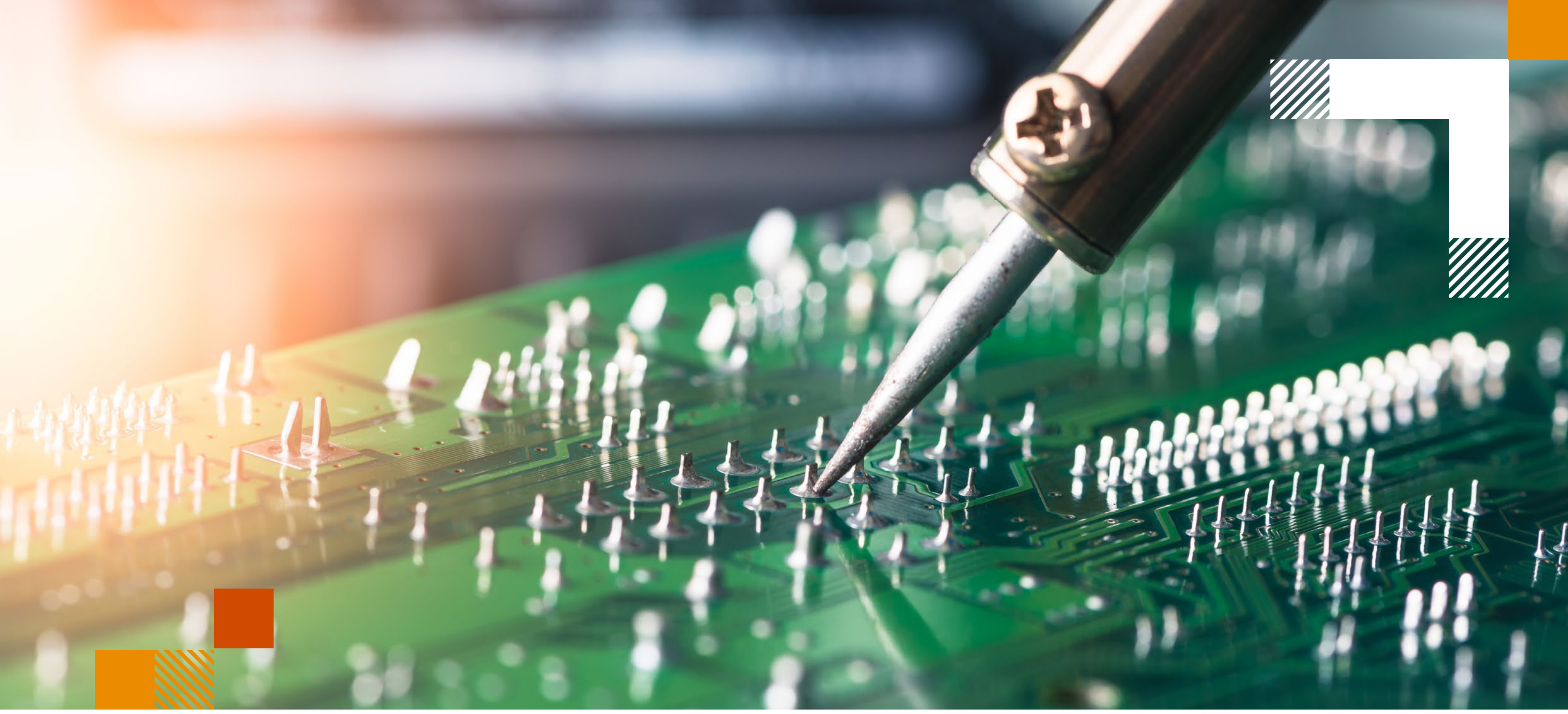
Competitive wages, highly skilled human resources and geopolitical nudges are pushing companies to explore India as the 'next' manufacturing destination. In the post-COVID era, India is one of the few large economies which shows encouraging indicators of economic growth with a low possibility of recession. India also has the potential to move past the US to become the world's second largest economy by 2040,[3] contributing 15% to the global GDP.

Strategic collaboration between India and other countries can facilitate the relocation of sub-component value chains to India, enabling local firms to develop niche advantages and achieve greater self-reliance in the production of electronics by consolidating value chains and leveraging the four most critical levers of the production system – technology, talent, trunk

1 MeitY Annual Report 2022-23 (p. 66)

2 https://pib.gov.in/PressReleasePage.aspx?PRID=1920586

3 PwC's 'The long view: how will the global economic order change by 2050'?



infrastructure and trade. Dissemination of knowledge to local supplier networks in India, mostly managed through MSMEs and emerging corporates, will emerge as a critical risk management strategy in this context.

Intermediate goods imported for further value addition help firm up a country's position in value chains.  The import of components showcases the increasing scale of assembly and related activities in India, indicating the scale of operations which leads to increase in economic gains and gives rise to employment opportunities to the citizens of the country. Experiences from other Indian industries, such as automobiles, have also shown similar growth trajectories.

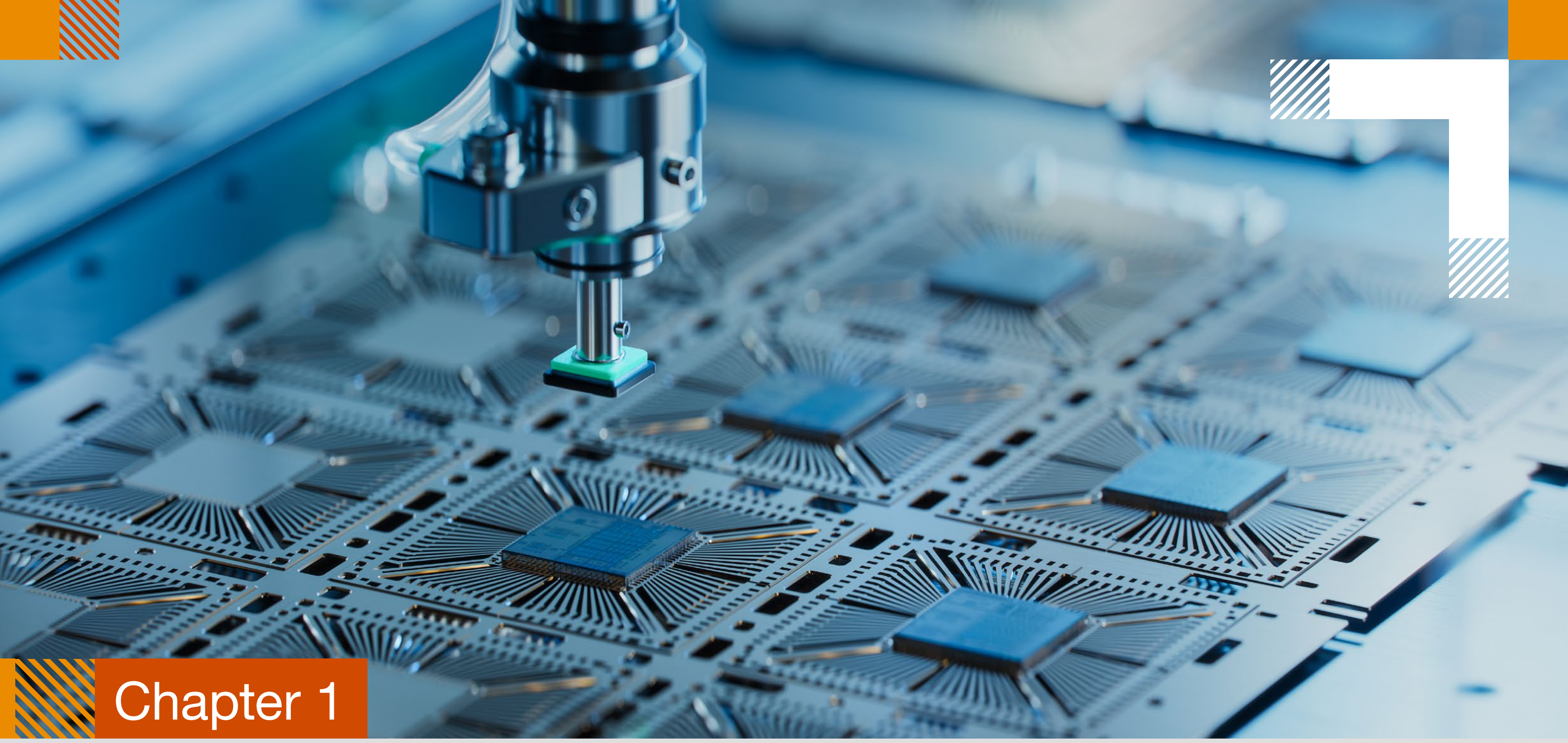
Securing critical mineral resources to achieve India's ambition of value chain localisation in electronics is also an important aspect of the electronics system design and manufacturing (ESDM) sector. Many countries also consider future/emerging technologies as an integral part of their mineral security. India needs to focus on leveraging its substantial reserves of some minerals as a means to access the resources the country lacks. This includes free trade agreements (FTAs) along with capacity-building initiatives to move up the value chain and maximise the returns from raw materials which are available in the country. For minerals where India faces a severe scarcity and high external dependence, it needs to ensure that it relies on friendly countries with low political risk to fulfil its commodity needs.

Efficient methods of production and manufacturing tend to elude the Global South due to strict intellectual property (IP) regimes and non-tariff methods to block competition and innovation. Targeted public spending on new technologies and acquiring IP is not getting enough attention. This has implications for cost and competitiveness in new sectors of manufacturing. Closing the IP gap is an important segment of the ESDM value chain ecosystem that must be addressed.

Given the capital-intensive nature of electronics manufacturing, the Government of India's Modified Special Incentive Package Scheme (M-SIPS) scheme provided incentives to the tune of 20–25% on capital expenditure to electronics manufacturing, including smartphone manufacturing and its ancillary industries.[4] Therefore, the capital infrastructure gap was not only bridged for the finished product, but also for its constituent components, thereby making the ecosystem sustainable and competitive in manufacturing smartphones.

India is uniquely placed among global economies, having garnered goodwill as a reliable partner for countries across the world. The country must now leverage this momentum to ensure that its internal strategy and operations enable it to become future-ready. A multi-pronged approach is essential to ensure that the centre of the ESDM sector in India holds firm. The next decade will be crucial for this given the window of opportunity for India to be a part of the value chain, created by the geopolitical context,  is very small. Decisive policy action is the need of the hour.

4 https://www.meity.gov.in/content/electronic-manufacturing-clusters-emc-0




# Introduction

The COVID-19 pandemic made countries across the world realise that they needed to focus on self-sufficiency to reduce their dependence on other countries. The intricate connections within global value chains (GVCs) pressured numerous countries, disrupting demand-supply balances across product and factor markets due to constrained market forces and supply-chain disruptions originating from China. These circumstances prompted governments to bolster domestic capabilities and attract investments to establish alternative manufacturing bases where India can also play a significant role. With the US-China trade conflict, the world had another rude awakening about the vulnerability created by its dependence on a small number of countries for the supply of critical raw materials, components, and products across sectors. These factors led to a slew of semi-protectionist measures from the Global North and an intense rethinking of trade policy in the Global South, with nearshoring, friendshoring, and reshoring at the centre of these policy measures.

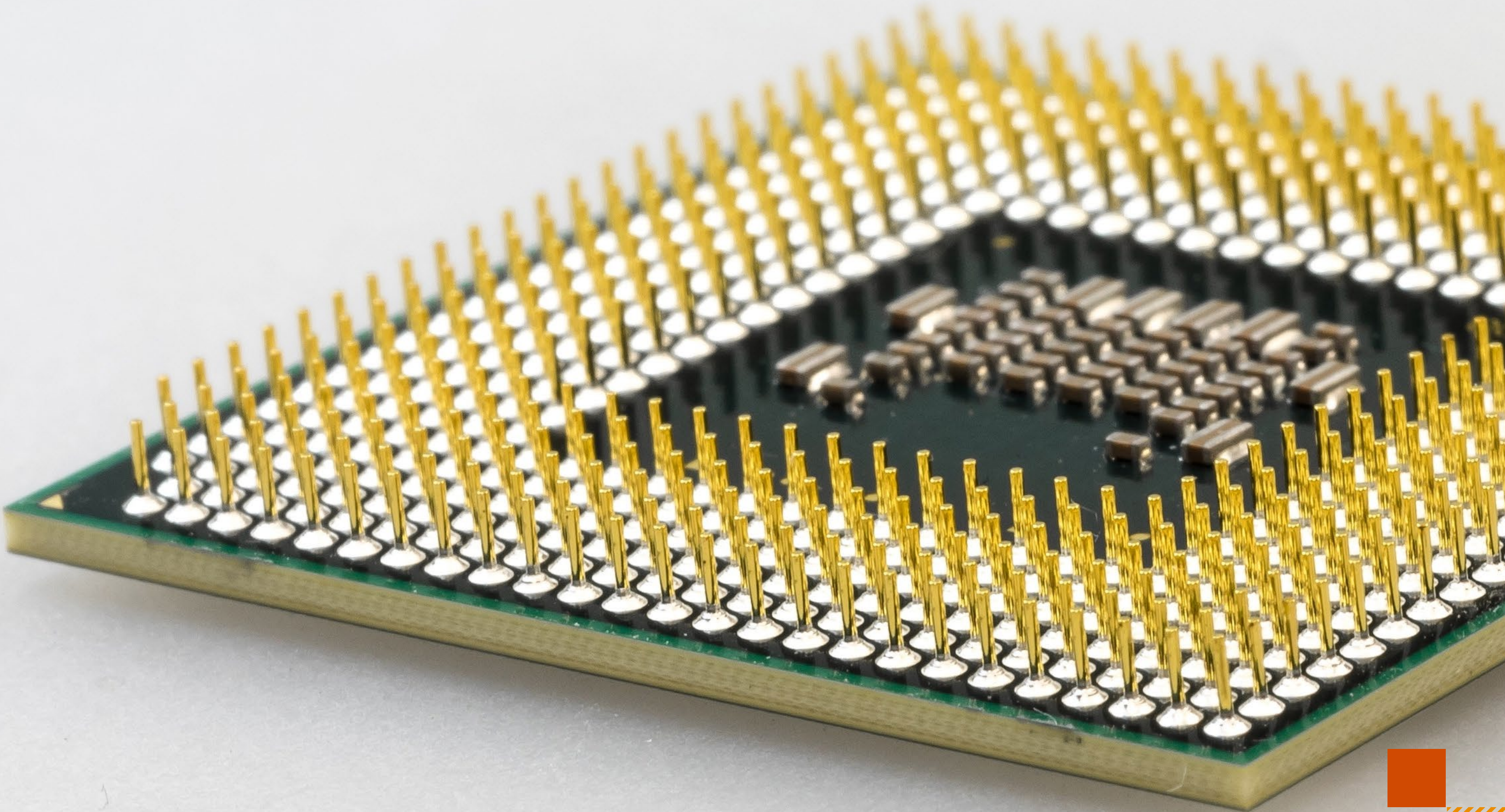
The COVID-19 pandemic has also driven governments to shift their focus from relying on inter-country advantages to fostering intra-regional and domestic self-sufficiency in value chains. The debate on the gains from international specialisation in GVCs versus its associated risks gained prominence as the focus shifted to the linkages among companies in value chains and emphasised the need for a broader governance perspective. Moreover, supply chain disruptions due to ongoing geopolitical conflicts in Europe, West Asia and other parts of the world further reinforced the call for greater self-sufficiency and alternatives to conventional manufacturing bases.

A critical sector which has been impacted by the evolving geo-economic dynamics is the electronics sector. From raw materials that go into the creation of chips to the components that go into the production of devices and the finished product – each aspect of the sector has witnessed value chain specialisations specific to certain geographies. For instance, foundry services of semiconductors are primarily located in Taiwan, while South Korea and Japan have a significant competitive edge in display and display fab technology. China has emerged as a strong contender in the electronics value chain's final assembly and component manufacturing segments. The geographic concentration of these services have disabled risk diversification for vital global players who are now susceptible to supply chain disruptions caused by geo-political conflicts, economic downturns, and black swan events like a global pandemic.

The modern way of life has made electronics a necessity for economic, strategic, and social needs. India's progress in electronic manufacturing which is demonstrated by the remarkable growth of the sector can be leveraged to integrate the country in the global manufacturing value chain. The Production Linked Incentives (PLI) Scheme is an important initiative to enhance domestic and international competitiveness in Indian industries, including electronics manufacturing organisations. As India moves towards self-sufficiency with a focus on expanding its export capabilities, policies which encourage collaborations, incentives, and global integration emerge as vital strategies in navigating the dynamic electronics landscape.

China's decision to enforce export controls on gallium and germanium in July 2023 caused short-term disruptions in Indian electronics industries due to interruptions of critical supply chains. The semiconductor industries in India are particularly susceptible to the impact of these export controls. Given the widespread use of chips in products like electronics and automobiles, the increase in prices of gallium and germanium could have a cascading effect on the economy, affecting both production cost and availability. However, the long-term consequences will depend on factors such as domestic semiconductor production capabilities, alternative supply sources, and strategic alliances, like the India-US Initiative on Critical and Emerging Technology (iCET).

Chapter 2 of this paper examines India's existing position at each ESDM value chain tier across various important segments. Subsequently, Chapter 3 maps India's position vis-a-vis critical minerals and the implications for the ESDM sector. Chapter 4 analyses the gaps in the ecosystem and how policymaking in India is aimed to fill these gaps. Chapter 5 recommends future policy actions that need to be taken at each level to take advantage of this limited opportunity to strengthen India's electronics manufacturing capabilities further and help the country emerge as a reliable global electronics manufacturing partner for the world.




# The components conundrum

## Introduction

The electronics sector has become one of the rapidly expanding sectors in the Silicon Age where dual forces of globalisation and the World Wide Web have generated a significant demand for electronic goods. The continuous digitisation of the world guarantees a sustained momentum in global electronics trade. In addition to concerns about energy security, the COVID-19 pandemic underscored the importance of 'electronic security,' as disruptions in the supply chain halted the production of components in various sectors, from automobiles to healthcare devices, leading to a scarcity of electronic parts.

The impact of the COVID-19 pandemic on electronic value chains was felt globally due to the regional concentration of various parts of the chain in East Asia, especially in China. The disruptions caused due to stringent COVID-19 restrictions in the region led to supply chain bottlenecks not just in electronics but also in other industries which use electronic components such as automobiles, IT hardware, telecommunication equipment, and the aerospace industry. The disruptions led to nations and private sector firms assessing their capabilities across electronics value chains and undertaking strategic measures to enhance their individual capabilities to manufacture critical components that could mitigate the risks associated with supply chain disruptions, and diversify their existing supply chains to alternate locations with greater geopolitical and economic alignment. India, owing to its comparative cost advantages and geo-political alignment, has emerged as a natural alternative for organisations that are looking to diversify their supplier base in Asia. Furthermore, India's domestic electronics demand, coupled with the presence of an evolved industrial ecosystem, supportive policy measures, and skilled human resource makes it the only alternative that can match the desired scale of production among its other East Asian peers, except China.

This chapter examines India's existing position at each tier of the ESDM value chain across crucial segments. It also focuses on identifying the key challenges which are impeding the growth of the sector and subsequently look at key recommendations for overcoming these challenges.

## Decoding electronics manufacturing in the global context – from components to devices

Electronics manufacturing can arguably be identified as one of the typical examples of a global value chain where the advantages of the design and production systems of the West (mainly the United States and Western Europe) merge with the production systems of the East (legacy players such as Japan and South Korea). In other words, firms divided the complete production processes which culminated into global value chains where key nodes were controlled by regional players with niche expertise. This phenomenon allowed electronics manufacturers to leverage the competitive advantages of each system. The typical distribution of a premier smartphone value chain has players ranging from North America in the West to Japan in the East with their respective competitive advantages. Design, product development, touchscreen controller units, flash memory, etc. are manufactured mostly in North America. Power management units, network components, and allied sub-systems are manufactured in Europe. Finally, components critical to functioning of the phone such as application processors, memory chips, Bluetooth, WiFi components, and assembly activities are mostly done in Asia. However, such distributions may change depending on the brand.

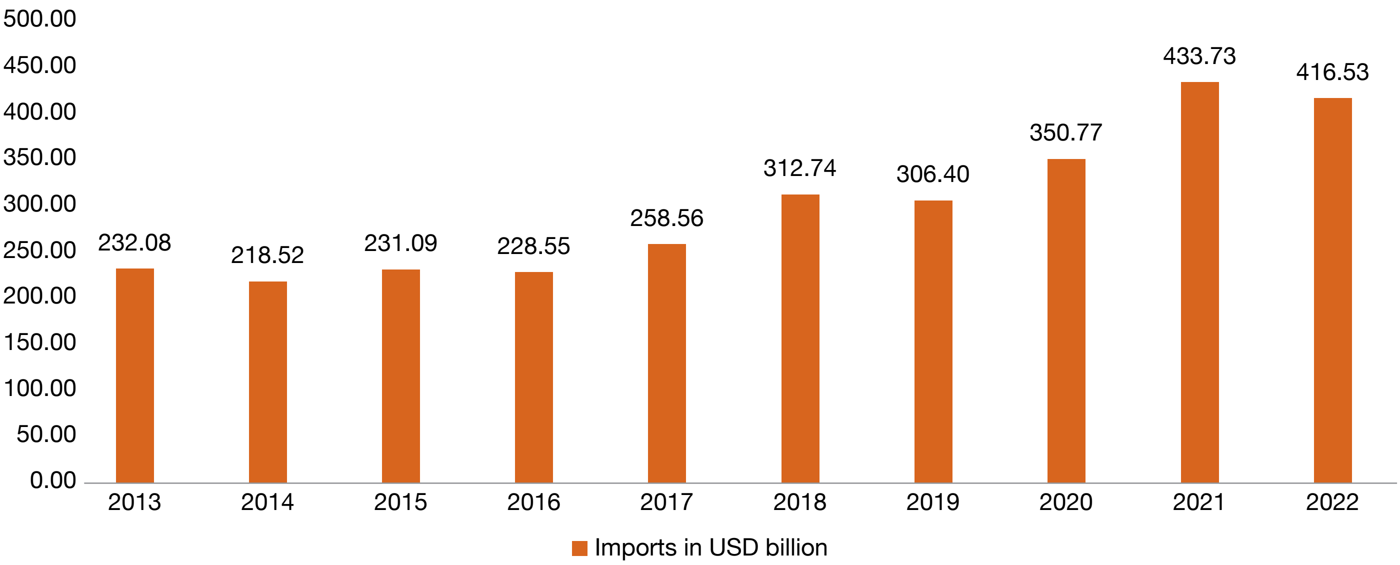
Like the finished products, the components which are included in these devices undertake a similar journey. For instance, a semiconductor chip that is used within the Bluetooth and Wi-Fi component of the premium smartphone can cross international borders as many as 70 times before it reaches the final consumer and the entire process may take up to 100 days, 12 of which are spent in transit between various supply chain steps.[5] Therefore, the components themselves are as critical as the final device. Onshoring device manufacturing, which entails the technical assembly of components into finished devices, is not enough to achieve supply chain resilience in electronics. Countries must also expand their capabilities to develop production systems that can manufacture the required components like display, casing and printed circuit boards (PCBs). However, component manufacturing is not an easy vision to achieve. Several East Asian countries have struggled to localise component manufacturing, even if they have achieved significant assembly capabilities in the recent times. Two major factors which hinder a nation's ability to expand its capability to manufacture components are:

1) availability of critical minerals

2) availability of ecosystem enablers.

While both these factors will be dealt with in subsequent chapters of this report, it is important to note that even developed ecosystems showcase component import dependencies for electronics. For instance, China is heavily dependent on the import of integrated circuits and micro-assemblies for manufacturing electronics.

**Figure 1: China's import of integrated circuits and micro-assemblies have grown to match its electronics manufacturing**




**Source:** https://www.trademap.org/Country_SelProductCountry_TS.aspx?nvpm=1%7c156%7c%7c%7c%7c8542%7c%7c%7c4%7c1%7c1%7c1%7c2%7c1%7c2%7c1%7c1%7c1

5 https://www.whitehouse.gov/wp-content/uploads/2021/06/100-day-supply-chain-review-report.pdf

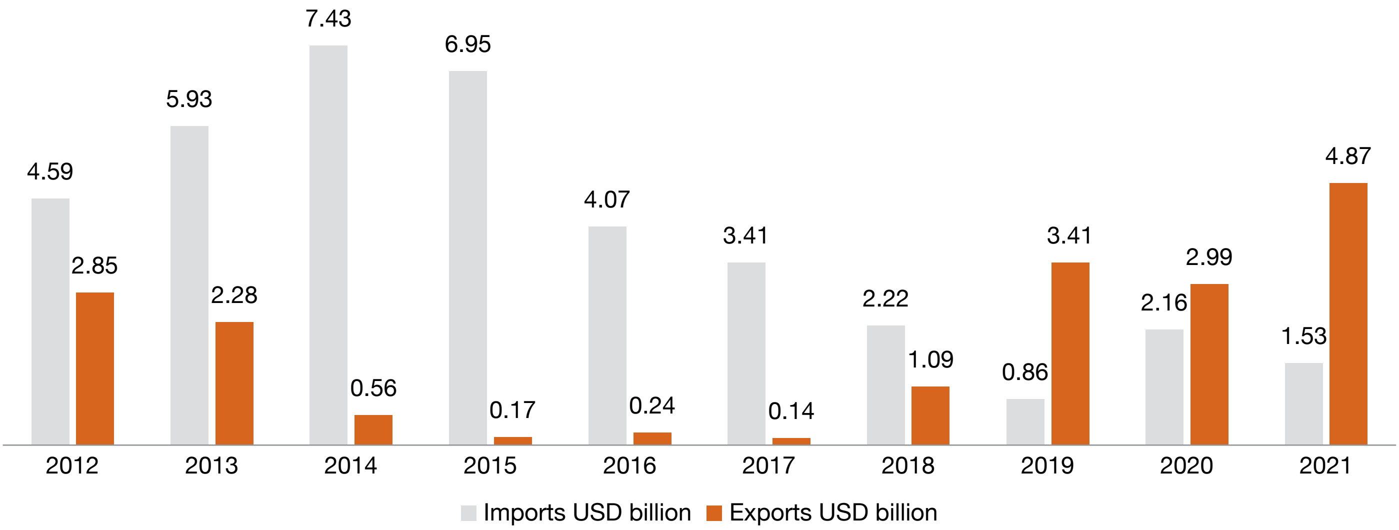
Some of the major challenges of the Chinese ESDM ecosystem's inability to localise ICs and micro-assemblies stem from the limited presence of ecosystem enablers such as design and IP firms, though the country has attempted to resolve its problem of limited reserve of critical minerals. While evolved ESDM ecosystems like China are yet to solve the chip puzzle, India's challenges around components are comparatively more basic than those of China. India's foray into electronics manufacturing started with the assembly of devices and gradually moved into select components across the value chain. While it is encouraging to witness the development, India's aspiration to emerge as an alternative destination to existing East Asian manufacturing centres will require the nation to develop its competence in electronics component manufacturing. Unless India can make a strong push for components, it will not be able to showcase itself as a resilient supply chain player to the world. In the next segment, we will take the example of one of the most used electronics devices in India – the smartphone – and analyse the maturity of India's value chain in manufacturing the device. While it is expected that complex components such as logic chips will continue to be imported for the time being, as is the case with most nations, localisation of significant portions of the supply chain is already on course, which is encouraging for both local and global manufacturers.

## Making in India – achieving progressive localisation in the country

Within ESDM sector, India's electronics manufacturing capability for the global market has been showcased primarily in four key sectors – mobile phones, consumer electronics, IT hardware, and electronic components – comprising more than 70% of India's domestic manufacturing landscape.[6] The electronics sector is unique in its transformation from being 78% import dependent in 2014,[7] to a period of import substitution in 2017–19 through the Atmanirbhar Bharat Abhiyaan, to the present export-led growth period with policies such the PLI scheme for smartphones. International companies have shown a keen interest to utilise these local capabilities to diversify their supply chains and establish their manufacturing operations in India.

India is the second-largest global mobile phone manufacturer and is establishing itself as the most rapidly expanding market for smartphones globally.[8] From 2015 to 2022, mobile phone production surged from 60 million to 310 million at an impressive compound annual growth rate (CAGR) of 26%.[9] The strategic inclusion of mobile phone manufacturing, along with its sub-assemblies and sub-components, as flagship initiatives within the Make in India programme has significantly bolstered the growth trajectory of the industry. Presently, the 200-plus manufacturing units for mobile phones, sub-assemblies, and components established in the past few years have employed approximately 7,00,000 individuals[10] – a compelling testament to the success of localised manufacturing that can serve as a model for other sectors. With India expected to have more than 1 billion smartphone users by the end of next year,[11] the domestic market for smartphones along with India's existing manufacturing system will further draw interest from global manufacturers to make their smartphones in India.

**Figure 2: India's journey as a global exporter of smartphones as further strengthened its position across global value chains**




**Source:** UNCOMTRADE: https://www.trademap.org/Country_SelProductCountry_TS.aspx?nvpm=1%7c699%7c%7c%7c%7c851712%7c%7c%7c6%7c1%7c1%7c1%7c2%7c1%7c2%7c1%7c%7c1

6 MeitY Annual Report 2022-23 (p. 66)

7 https://economictimes.indiatimes.com/industry/cons-products/electronics/99-2-per-cent-of-mobiles-made-in-india-ashwini-vaishnaw-reviews-meteoric-growth-of-indi mobile-sector/articleshow/105496885.cms?from=mdr

8 https://pib.gov.in/PressReleasePage.aspx?PRID=1920586

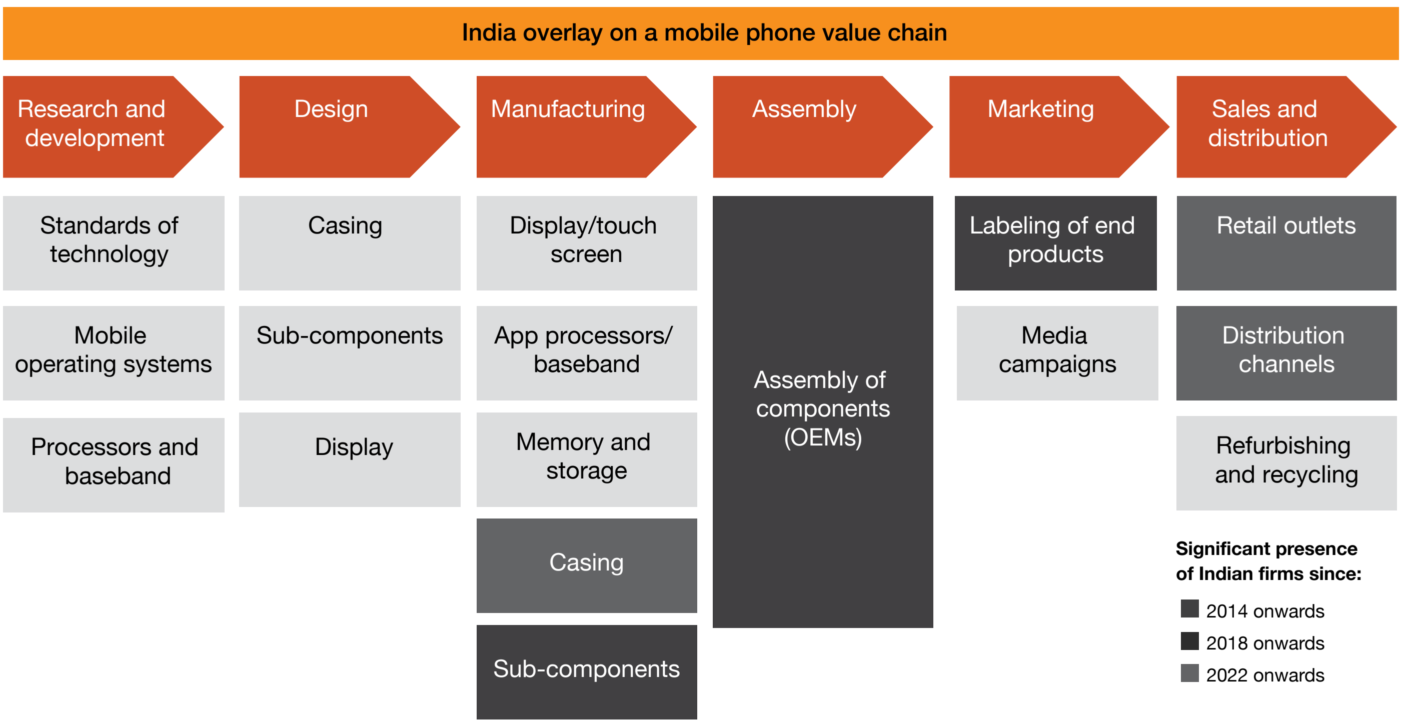
9 https://pib.gov.in/PressReleasePage.aspx?PRID=1920586

10 https://indianexpress.com/article/technology/tech-news-technology/india-now-has-268-mobile-handset-and-component-units-6-7-lakh-jobs-created-icea-5457529/

11 PwC analysis

India's development of its smartphone production systems is a good example to understand how nations can catalyse manufacturing system through clear policy objectives. India's growth in manufacturing is not only limited to the import substitution of its own demand but has also positioned the country as a manufacturer of smartphones for the world which is evident in the country's export of smartphones experiencing a 35x growth between FY2017 and FY2021.[12] However, India's growth has not merely been on assembly activities. Global firms operating in India, as well as new entrant Indian firms, have been expanding their footprint across the smartphone value chain. Export policies such as the PLI scheme for smartphones have helped the Indian electronics industry boost its capabilities and the current estimated worth of the industry is at USD 101 billion, with USD 23.6 billion electronics exports and USD 11.1 billion smartphone exports.[13] The sector has created 2.5 million jobs since 2014.[14] According to reports,[15] within 2.5 years, a single lead firm in the smartphone manufacturing space in India has created over 2,50,000 indirect and 1,20,000 direct jobs, of which 70% are held by women between the age of 19–24 years.

**Figure 3: Indian firms have expanded their presence across newer segments of the mobile phone value chain in the last 5 years**




**Source:** PwC analysis

12 UN COMTRADE Data, accessed January 21, 2024

13 https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1932051

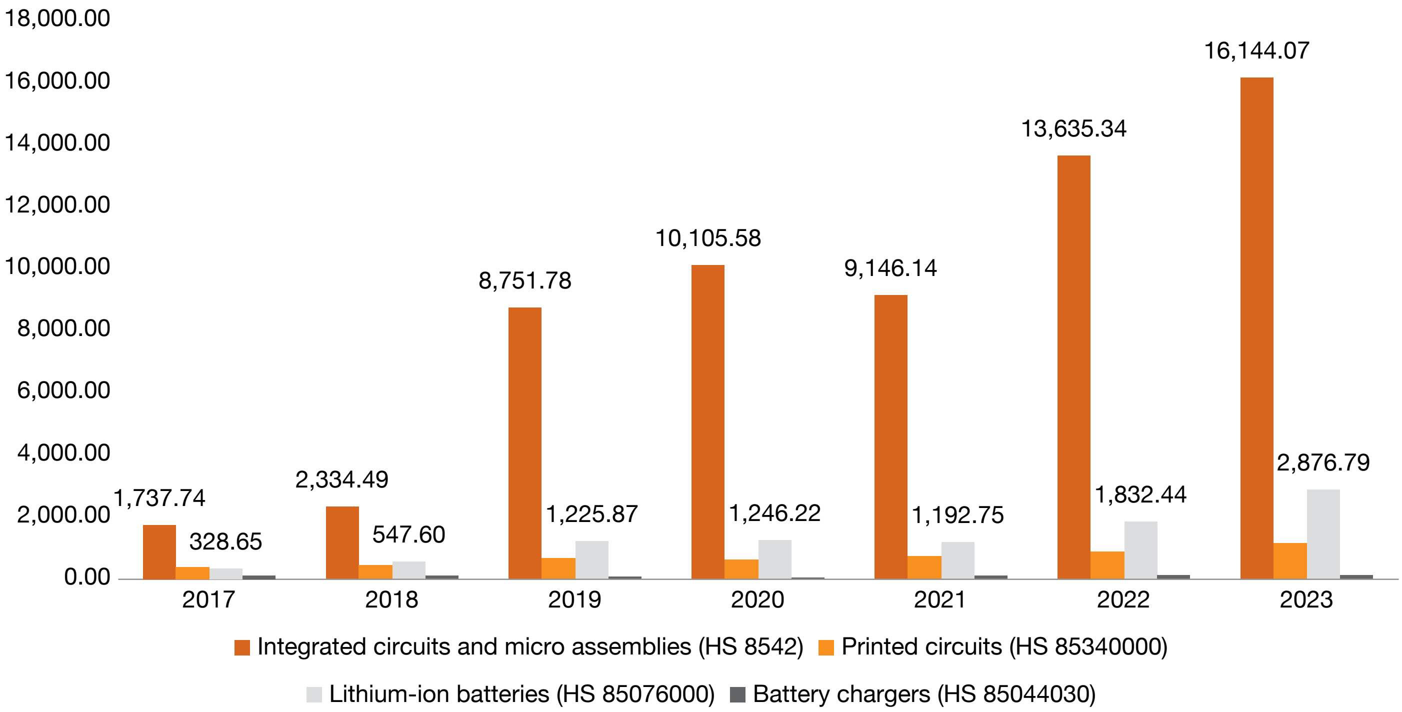
14 https://timesofindia.indiatimes.com/business/india-business/domestic-electronics-manufacturing-up-4-fold-to-rs-8-22-lakh-crore-in-fy23-mos-it/articleshow/105787799.cms?from=mdr

15 https://www.business-standard.com/india-news/apple-generated-1l-plus-direct-jobs-in-india-in-2yrs-70-for-women-mos-it-123041800459_1.html

While the initial phase of mobile phone manufacturing in the country was dominated by white-label imports that were branded by indigenous retail chains, the next phase saw the import of semi-knocked-down (SKD) and completely knocked-down (CKD) kits which were assembled in India. Since 2014, the assembly process moved to India through global original equipment manufacturer (OEMs) and electronics manufacturing services (EMS) players who were gradually expanding their presence. Currently, several Indian players have started acquiring the technical know-how from international players and have ventured into manufacturing components such as casings for premium segment phones.

While Indian firms continue to expand their presence across the value chain by venturing into new segments, it is imperative to note that Indian electronics manufacturing is still dependent on the import of critical components. As seen in the case of China, imports may not necessarily be a bad thing. Intermediate goods imported for further value addition can help firm up a country's position in value chains. The import of components showcases the increasing scale of assembly and related activities in India, indicating the scale of operations which leads to increase in economic gains and gives rise to employment opportunities to the citizens of the country. Experiences from other Indian industries, such as automobiles, have also shown similar growth trajectories.

**Figure 4: India's strengthening assembly capability has led to increasing import of electronic components – especially integrated circuit and micro assemblies**




**Source:** EXIM Dashboard, Ministry of Commerce and Industry, Government of India.

However, the dependence on external vendors for components does weaken India's case for supply chain resilience. To be seen as a reliable supplier of electronics for the world, India must overcome the weaknesses that were demonstrated by competing regional manufacturers – the inability to produce the final products due to supply chain disruptions. This has created a conundrum for India wherein the country must achieve resilience in supply chains through localisation of components along with manufacturing the final devices. Currently, complex electronics manufacturing in India is largely dependent on the relocation of foreign units to India bringing their own technology and production practices. Such relocation is dependent on the ability of foreign firms to leverage low factor costs of production and the ability to import components into India due to low tariff trade routes facilitated by FTAs, especially in comparison to the peer East Asian nations. Supply chain disruptions like constraints in navigating maritime routes, alterations in tariff policies, and unexpected events like the COVID-19 pandemic and geopolitical conflicts frequently challenge supply chain resilience. The best way to hedge such risks and achieve resilience is to localise supply chains within India. However, localising electronics supply chain is not easy. As electronics global value chains (GVCs) have given rise to regional expertise, manufacturing a device would require international collaboration, especially with players who control the technology, raw materials, or both besides leveraging on its own capabilities.

## From specialisation to control – exploring the oligopolistic nature of components markets

India's dependence on foreign firms for sourcing components is indicative of a larger and, perhaps, a more concerning characteristic of international components market. Its regional dependence on key players built over-time due to organic advantages (e.g. Japan owing to its R&D infrastructure) and international policy support and cooperation (e.g. Taiwan, which aligned most of its manufacturing capability through proactive support from the US and US firms, including the transfer of knowledge resources).

For instance, out of all the display components or touchscreens which are used to manufacture consumer electronics or consumer appliances, China (40.4%) and South Korea (36.3%) control ~77% of the market.[16] Compared to the Organization of the Petroleum Exporting Countries' (OPEC) 30% control of the oil market,[17] the regional dependency of display units is approximately 2.45 times higher than the regional dependence for crude oil, thereby making the market of display units almost oligopolistic in nature and susceptible to the risk of being influenced by geo-political influences. Thus, the alignment of countries across the global ESDM supply chain will be critical for their 'manufacturing security'. It also indicates a critical procurement risk where downstream industries – such as assembly – can be significantly impacted leading to unstable industrial ecosystems in India.

While it may not be possible to consolidate a complete value chain in a single geography since the intellectual property of critical components – such as display units or touchscreens – is heavily concentrated in certain geographies, strategic collaboration between countries can facilitate the relocation of sub-component value chains to India enabling local firms to develop niche advantages and achieving greater self-reliance in electronics production by consolidating value chains and leveraging the four most critical levers of the production system – technology, talent, trunk infrastructure, and trade. It will also help the country to disseminate the knowledge to its local supplier networks which are mostly managed through micro, small and medium enterprises (MSMEs) and emerging corporates. Another way to building local capabilities to safeguard the supply chain from risks is to leverage the bi-directional flow of technology and skills through trade besides building on existing natural endowment, i.e. oligopoly of critical minerals (as discussed in the next chapter).

To be able to convince partner countries to share technology, talent and the technical know-how for creating complementary infrastructure (e.g. cutting edge surface mount technology (SMT) lines and clean rooms to produce components such as direction of arrival (DOAs) and non-legacy semiconductors) and resilient trade engagements, India will need to position its own economic and geopolitical advantage as the natural alternative to existing manufacturing champions such as China. In this regard, India's organic market, existing Science, Technology, Engineering and Mathematics (STEM) talent pool, focused policy initiatives, and stable geo-political alignment will support long-term migration of component manufacturing to India as firms to seek ways to diversify production and consolidate value chains around new markets in electronics.

16 https://www.globaltimes.cn/page/202204/1260373.shtml

17 https://www.bbc.com/news/business-61188579

## Attracting component manufacturers to India – leveraging factor cost advantages, macro-economic fundamentals and growing infrastructure

China and Vietnam accounted for 72% of global mobile phone exports as of 2021.[18] Manufacturing operations of these leading firms would need to shift to India for the country to establish itself in the GVC. To attract substantial investments, India needs to create an attractive manufacturing and exporting ecosystem with suitable incentives and improved ease of doing business. Bringing in manufacturing abilities from both global and domestic firms would create economies of scale and stimulate domestic capacity building through technology transfers from global players.

Competitive wages, highly skilled human resources and geopolitical nudges are pushing companies to explore India as the 'next' manufacturing destination. In the post-COVID era, India is one of the few large economies demonstrating positive indicators of economic growth with a low possibility of recession. Maintaining the momentum of favourable growth trends, it is no wonder that by 2040, India could edge past the US to become the world's second largest economy contributing 15% to the global GDP.[19] The country has created a strong economic base and looks poised to achieve the status of a developed country over the next 25 years. India's global preference as a destination for foreign direct investment (FDI) remains consistent as it has attracted FDI of over USD 903.9 billion between 2020 and 2022, the years which were most impacted due to the COVID-19 pandemic. India has also leapfrogged in ease of doing business (EoDB) rankings, jumping 79 positions between 2013 and 2020.[20] All these factors have propelled the country's new image as a destination of choice for manufacturing firms across the globe.

The same image can now be strategically leveraged to develop component manufacturing in India for international players.

Along with strong macroeconomic fundamentals, India continues to be extremely competitive around factor costs when compared to peers such as China, Thailand and Vietnam. For instance, India's minimum monthly wage (MMW) is 46% of the MMW in Thailand. Moreover, the size of the labour force in India is approximately 12 times of that in Thailand. India has also surpassed China to become the most populated[21] nation in the world. While wage inflation has outpaced productivity gains in most regions, labour cost inflation has been lowest (18%) in India compared to Mexico (18%) and China (24%).[22] As a result, India remains one of the most cost-competitive manufacturing destinations.

India's 26% population belongs to the age group of 15–29 years and another 26% falls within 0–14 years of age.[23] This agile and aspirational population is all set to become the next demographic driver for the global economy, especially for labour-intensive manufacturing. The working age population in India is expected to grow till as late as 2050, and India's median age is lower than China by almost 11 years.[24] The availability of cheap labour at scale remains one of India's biggest strengths in attracting manufacturers to India, and especially to emerge as an appropriate and competitive alternate to China, both in terms of scale as well as cost.

India's strong macroeconomic fundamentals are complemented by the growth of its digital economy. Furthermore, with the Digital India initiative, people of all age groups are becoming more connected through the internet. Between 2017 and 2022, the total number of internet subscribers have grown at a CAGR of 15%, crossing 850 million by end of 2022.[25] Digital payments too have seen a CAGR of 46% between FY18 and FY22 crossing the 92 billion transaction mark by end of 2022.[26] According to a study undertaken by the Observer

18 https://icea.org.in/blog/wp-content/uploads/2021/02/DisabilityReport.pdf
19 PwC's 'The long view: how will the global economic order change by 2050'?
20 PIB, DPIIT, PwC analysis
21 https://www.theguardian.com/world/2023/apr/24/india-overtakes-china-to-become-worlds-most-populous-country
22 https://economictimes.indiatimes.com/news/economy/foreign-trade/on-american-shelves-made-in-india-is-slowly-replacing-made-in-china/articleshow/105070158.cms
23 https://mospi.gov.in/sites/default/files/publication_reports/Youth_in_India_2022.pdf
24 https://www.thehindu.com/business/Industry/india-transformed-in-less-than-a-decade-morgan-stanley/article66915607.ece
25 https://www.trai.gov.in/sites/default/files/QPIR_03022023_0.pdf
26 PIB India

Research Foundation, the percentage share of nominal GDP for digital transactions could reach 56.9% by 2025–26.[27]

The ever-growing digital economy has set the foundation for a strong local demand of electronics in India, which has also become one of the key drivers for attracting electronics manufacturing organisations in the country. India's domestic demand for consumer electronics is expected to touch USD 21.18 billion by 2025 which coincides with the Government of India's ambitious target of achieving USD 300 billion domestic electronic manufacturing by the same period.[28] This can attract component manufacturers to set up their manufacturing units in India, which can help the country develop supply chain resilience in electronics by reducing their dependence on foreign suppliers, and improving local capacity by localising additional segments of the electronics value chain.

Another major factor driving India's manufacturing potential is its massive focus on high-quality industrial infrastructure to enhance manufacturing competitiveness. The National Infrastructure Pipeline (NIP) – a first of its kind comprehensive plan to increase quality of life and ease of living in India is focused on development of 2000+ projects worth over USD 1,800 billion. Similarly, 11 industrial corridor projects have been approved across major manufacturing hubs of Bengaluru, Chennai, Delhi, Mumbai, and other cities. The Prime Minister Gati Shakti National Master Plan has emerged as an institutional mechanism to drive last-mile connectivity in India through critical infrastructure gap projects and port connectivity initiatives. By improving efficiency and reducing costs associated with logistics, the plan aims to resolve the bottlenecks in setting up manufacturing operations in India.

27 Renita D'Souza and Nilanjan Ghosh, "India's UPI Market: Projections for Growth Under Various GDP Scenarios," ORF Occasional Paper No. 413, September 2023, Observer Research Foundation. Retrieved from https://www.orfonline.org/research/indias-upi-market

28 https://www.investindia.gov.in/team-india-blogs/indias-emergence-global-electronics-manufacturing-hub

## Challenges for component manufacturers in India

Currently, high logistics costs remain one of the major disadvantages for component manufacturers to consider India as a possible alternative manufacturing destination in Asia. Components move across borders as per the regional specialisations. Higher costs of logistics can significantly impact the bottom-line of components manufacturers in any country, hence the comparatively higher logistics costs remain a challenge for component manufacturing in India. As per industry estimates,[29] the transportation cost (freight charges and transportation to plant from the nearest airport/port) of a premium category smartphone manufactured in China is USD 0.80. This cost can go as high as USD 8 in India depending on the location and distance of the port/airport and the plant from where it is being manufactured.

**Table 1:** Both China and Vietnam have lesser lead times to gateways resulting in reduced costs. Logistics remains a key challenge for component manufacturers to move their operations India.

| Category | India | China | Vietnam |
|---|---|---|---|
| The World Bank's Logistics Performance Index 2023 (Rank) | 38 | 19 | 43 |
| Infrastructure (Rank) LPI 2023 | 47 | 14 | 47 |
| Logistics competence (Rank) LPI 2023 | 38 | 20 | 53 |
| Average distance (port or airport supply chain) in km and lead time (in days) for exports* | 246 (3 days) | 337 (2 days) | 43 (2 days) |
| Average fuel costs (per litre) in USD for diesel | 1.123 | 1.017 | 0.81 |
| Average time for clearances | 3–4 days | 1–2 days | 1–3 days |

**Source:** The Logistics Performance Index and Its Indicators, World Bank; https://www.globalpetrolprices.com/diesel_prices

*From the point of origin (the seller's factory, typically located either in the capital city or in the largest commercial center) to the port of loading or equivalent (port/airport), and excluding international shipping (EXW to FOB).

The other major challenge for component manufacturers is the availability of quality raw material required to manufacture precision components such as PCBs and semiconductor fabrication units or fabs. While India has several mature industries that can potentially supply materials to component manufacturers, their maturity to produce industrial grade products is yet to be achieved. For instance, an assessment by India Electronics and Semiconductor Association (IESA) has revealed that India can critically support the manufacturing of semiconductors, the most critical component in electronics manufacturing, by providing chemicals and gases from its chemical industry.[30] Along with domestic component manufacturers, this can also be exported to other nations that are reconsidering their import relationships due to geopolitical shifts. However, to become a reliable supplier, the Indian chemical industry will have to augment its capabilities in manufacturing the desired standard of the raw material for semiconductor industries.

29 PwC analysis

30 IESA Semiconductor Manufacturing Supply Chain Report 2022

**Figure 5: India needs to achieve readiness and maturity across supporting industries, like chemicals, to localise component manufacturing and build supply chain resilience**

| Materials | Global benchmark for the semiconductor industry | Indicators | | |
|---|---|---|---|---|
| | | Availability | Readiness | Maturity |
| Sulfuric Acid | 98% concentration | Green | Yellow | Yellow |
| Hydrochloric Acid | 37–38% concentration | Green | Green | Green |
| Ammonia | Purity level of 99.99% | Green | Yellow | Yellow |
| Hydrogen Peroxide | 30% concentration, ultrapure | Green | Green | Green |
| Nitric Acid | 70% concentration | Green | Green | Yellow |
| Acetic Acid | 99% in VLSI-quality | Green | Yellow | Red |
| Ethanol | 70–90% concentration | Green | Green | Green |
| Acetone | >99.5%, ULSI Grade | Green | Green | Yellow |
| Carbon | 99.995% purity | Green | Green | Green |
| Phosphoric Acid | Greater than 99% purity | Green | Yellow | Red |

**Source:** IESA
**Green:** High **Yellow:** Moderate **Red:** Low/negligible

Apart from logistics and other supporting industries, another operational challenge for establishing component manufacturing businesses in India is the availability of a skilled workforce, both for craftsmanship and for engineering the components. Adequate capacity building through programmes such as Pradhan Mantri Kaushal Vikas Yojana (PMKVY), Deen Dayal Upadhyaya Grameen Kaushalya Yojana (DDU-GKY), and skill training at industrial training institutes will be critical to equip the workforce with the necessary skills for the component manufacturing industry.

## Solving the conundrum – establishing component manufacturing industries in India

Electronic components are as critical for building supply chain resilience as the ability to manufacture the final product. Over the years, India has shown remarkable progress in expanding its geographic footprint across the electronics value chain, as illustrated with the case of smartphones – one of the most widely used and relatively complex products. India's competitive factor costs compared to its regional peers, sound macroeconomic fundamentals, a growing digital economy fuelling the demand for electronics and evolving industrial infrastructure can become an attractive proposition for global and regional manufacturers to set up their base in India.

However, there are some critical challenges which hinder the shift of component manufacturing to India. Higher logistics cost, low maturity of supporting industries and limited skilled workforce for specialised production systems required for manufacturing components (such as training to work at SMT lines) deter component manufacturers from entering local electronics manufacturing ecosystems. By facilitating seamless regional and national connectivity, developing local support industries and developing the right talent pool, India can establish itself as an attractive destination for component manufacturers. Regions in India which have been able to address some of these aspects have been able to foster component manufacturing. Component manufacturers of a premium smartphone manufacturer are already in discussion with several Indian states to migrate their facilities into India. However, to realise these opportunities, the resolution of the above challenges would be critical. It is also important to resolve the two most fundamental challenges for long-term supply chain resilience of component manufacturing – the development of appropriate ecosystem enablers and the availability of critical minerals for manufacturers in India.

Chapter 3

# Critical minerals – securing the future

In the last five years, trade wars and regional conflicts across the globe have resulted in significant insecurity about supply chains for essential goods and services. Critical minerals play a key role in this realisation of the costs of overdependence on a single supplier. We have already analysed India's electronics supply chain potential, and now shall focus on assessing the fundamentals required to realise it.

Critical minerals are deemed crucial for economic development and national security but are at risk due to supply chain vulnerabilities such as domestic scarcity and geopolitical tensions. The criteria to decide the criticality of specific minerals differ for each country, based on their level of development as well as larger economic goals. Identifying these minerals allows governments to stabilise supply – either by investing in domestic production, diversifying sources or developing alternative materials. In 2023, India identified 30 critical minerals[31] based on their level of economic relevance, supply risk – or a combination of the two. This identification exercise revealed the dire need for restructuring the critical minerals supply chain. For some of these minerals, India is fully or partially dependent on external sources, making the supply chain highly concentrated and, therefore, more vulnerable to risks.

In this chapter, we discuss the importance of securing critical mineral resources for India's ambition of value-chain localisation in electronics. We also focus on the approaches adopted in other countries with respect to mineral security, which consider the inclusion of future or emerging technologies as an integral part of their economy. We will highlight select minerals that are essential for India's progress up the smile curve of production activities and mineral availability in India to realistically assess the possibility of reducing foreign dependence for electronics manufacturing. We also outline various sectors across which critical minerals have significant impact, including semiconductors, consumer electronics, aerospace and defence electronics production. Furthermore, we broadly review the need for making use of existing FTAs and forging new ones to leverage strategic partnerships for securing our minerals supply.

31 https://mines.gov.in/admin/storage/app/uploads/649d4212cceb01688027666.pdf

## Context

Securing critical minerals supply is necessary for the future of our economic growth as these form the building blocks of both digital and green transformation. As discussed in the earlier chapter, the ESDM sector alone was valued at USD 90 billion in FY19 in India,[32] and is predicted to reach approximately USD 220 billion by 2025.[33] As India aims to become a USD 300 billion electronics manufacturing hub by 2026,[34] its growth is intrinsically linked to localising the supply chain in order to develop full-stack manufacturing capabilities, which is further linked to securing critical minerals. In the new Public Sector Enterprise (PSE) Policy of 2021,[35] the Ministry of Finance, GoI divided PSEs into strategic and non-strategic sectors. The policy has retained a broad category of 'important minerals' as a strategic sector.

Critical minerals are key elements that would facilitate the development of new technologies due to their role in the creation of semiconductors or chips. Moreover, market competition to create more efficient semiconductors has become a matter of both economic and national security due to the growing use of these chips in the defence manufacturing sector as well. This weaves a complex web of dependencies.

Transistors are made up of either pure metals or rare-earth elements (REEs), which are collectively called critical minerals. Moore's law projects that the number of transmitters per silicon chip will double every two years.[36] For context, in 2020, a high-end smartphone used chips with 16 billion[37] transistors. The latest chips used in this flagship smartphone can have between 40 billion to 67 billion transistors.[38] So, in the space of two years the number of transistors used in this one product went up 4.18 times. This implies a concomitant increase in the demand for rare earth elements.

Considering the limited availability of such elements, countries that have an abundant supply and control over them often end up becoming the gatekeepers of innovation and technology – e.g. China has cornered the market for the export of gallium and germanium which are new-age replacements for silicon due to their higher conduction capacity.[39] The recent export curbs placed by China on gallium and germanium will have far-reaching impacts on the technology sector – especially for manufacturers in Europe and the US.

In terms of the green transition, the shift to electric vehicles (EVs) and other non-fossil fuel-based technologies also requires the use of critical minerals for their production. Given India's commitments to reduce greenhouse gas emissions and reach net zero by 2070, the demand for critical minerals is set to rise significantly. For instance, demand for silicon and gallium for solar panels is projected to increase by 1.8 times in five years.[40] Moreover, the demand for lithium due to its importance in rechargeable batteries is projected to increase by 3.5 times within five years.[41] This is a core issue mentioned in the US's Inflation Reduction Act of 2022.[42] Furthermore, the extraction, production and processing of critical minerals take a toll on the environment[43] as these minerals are obtained through mining or are the by-products of mined and semi-processed minerals.

32 https://www.ibef.org/industry/electronics-system-design-manufacturing-presentation

33 https://www.ibef.org/industry/electronics-system-design-manufacturing-esdm/

34 https://indbiz.gov.in/govt-forms-board-to-make-india-a-us-300-billion-electronics-manufacturing-hub/

35 https://xn--j2bim4e.xn--11b7cb3a6a.xn--h2brj9c/dipam_docs/strategicDisinvestment/New_PSE_Policy_for_Atmanirbhar_Bharat.pdf

36 https://www.economist.com/science-and-technology/2023/12/13/jensen-huang-says-moores-law-is-dead-not-quite-yet

37 https://www.thehindu.com/sci-tech/technology/gadgets/apple-silicon-m1-chip-explained-16-billion-transistors-neural-engines-secure-enclave/article33070321.ece

38 https://timesofindia.indiatimes.com/gadgets-news/apple-unveils-m2-pro-and-m2-max-processor-for-mac-devices/articleshow/97064951.cms

39 https://www.bbc.com/news/business-66118831

40 https://csep.org/blog/projecting-critical-mineral-needs-for-indias-renewable-electricity-transition/

41 https://csep.org/blog/projecting-critical-mineral-needs-for-indias-renewable-electricity-transition/

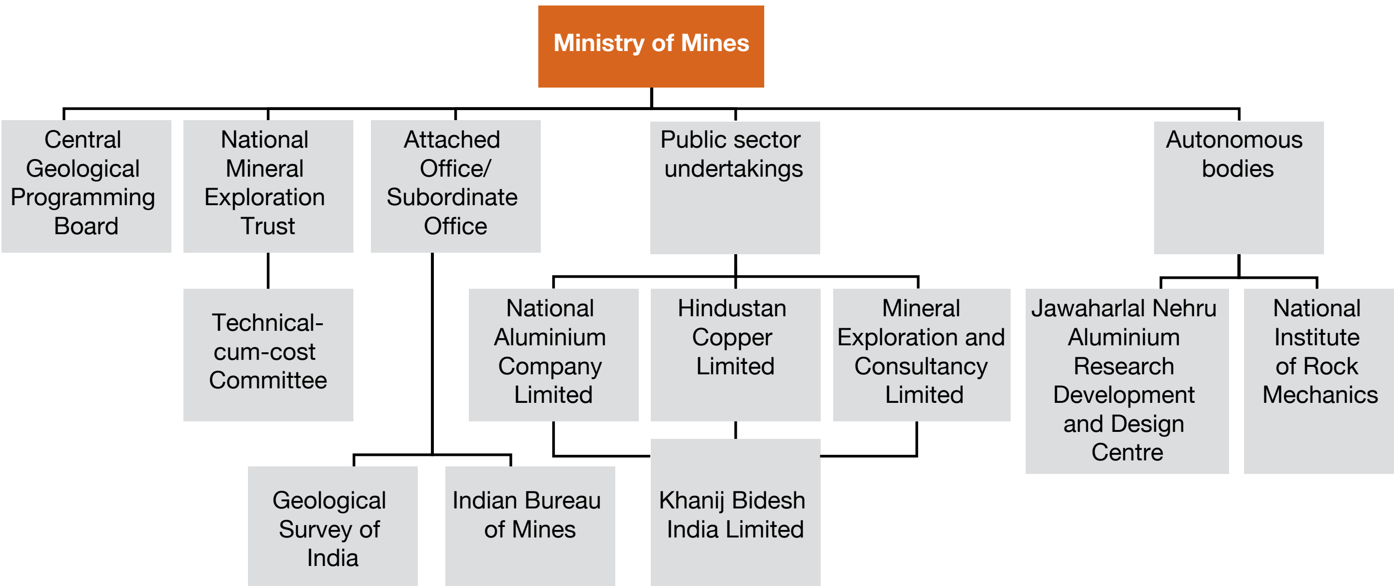
42 https://www.whitehouse.gov/wp-content/uploads/2022/12/Inflation-Reduction-Act-Guidebook.pdf

43 https://www.ft.com/content/1d3e72fb-9c6d-48da-963d-31afd456850f

## Critical minerals in India

Access to critical minerals is a major vulnerability in India's technology supply chains. Although 125 critical minerals exploration projects were taken up in 2023,[44] at this stage, we can admit that India may never have enough natural reserves of some important minerals. Moreover, the existing reserves come with their own set of challenges and ecological concerns. The discovery of lithium reserves in Jammu and Kashmir in 2023, for instance, has already raised widespread concerns about the socio-environmental impact of their extraction.[45] Balancing these legitimate concerns with the real strategic need to secure the supply of critical minerals is the policy tightrope India currently needs to tread. Their diverse applications and importance in strategic sectors such as aerospace, defence and emerging technologies are amongst the many reasons why securing critical minerals is occupying policy conscience now. The significant dependence of a wide range of industries on these materials in the absence of domestic production further emphasises the need for reliable sourcing.

**Figure 6: Regulatory ecosystem of critical minerals in India**



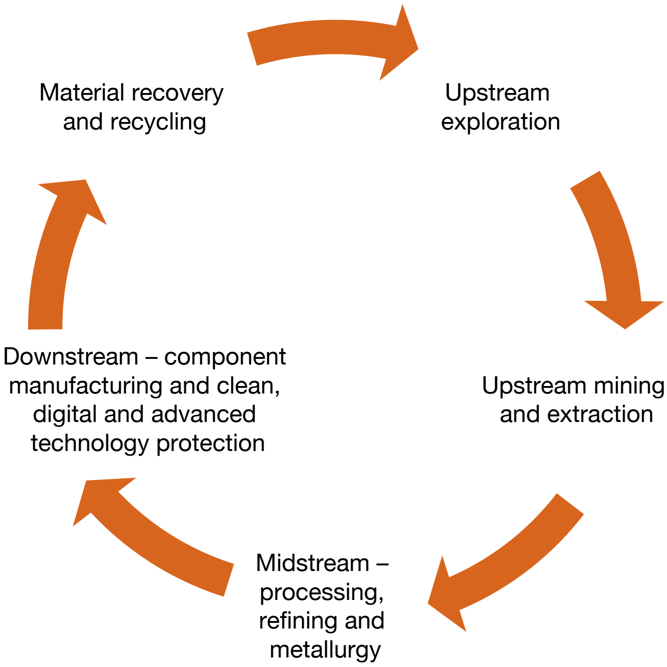

**Source:** Authors' visualisation based on Ministry of Mines, Annual Report 2022–23

44 https://timesofindia.indiatimes.com/business/india-business/govt-says-125-new-projects-taken-up-for-exploration-of-critical-minerals/articleshow/105598769.cms?-from=mdr

45 https://www.thehindu.com/sci-tech/science/explained-why-indias-lithium-discovery-is-fraught-with-social-and-environmental-risks/article66507035.ece

The Ministry of Mines has set up an extensive network of regulatory, research, exploratory and consultancy bodies to promote the development of critical mineral supply chains in India. Extraction, storage, transport, processing and final use – all stages of supply chain have their own unique challenges when it comes to securing critical minerals. Therefore, India will have to invest in infrastructure and policy solutions from the start to finish to ensure that it is not caught off guard when geopolitics inevitably intervenes in geoeconomics.

### Figure 7: Pillars of the critical mineral value chain




**Source:** Authors' visualisation based on Ministry of Mines, GoI report

The table below shows the 30 identified critical minerals according to the Indian Ministry of Mines as well as the 15 for which India is fully or nearly fully dependent on imports.

### Table 2: India's critical minerals

| Sr. no. | Mineral/element | Import dependence | Use*** in ESDM sector |
|---|---|---|---|
| 1. | Antimony | | Solar panels, semiconductor production for diodes and infrared detectors |
| 2. | Beryllium | * | Aerospace and defence materials, nuclear reactors and X-ray windows |
| 3. | Bismuth | | Semiconductors – particularly in lead-free solder alloys |
| 4. | Cobalt | | Lithium-ion battery cathodes for portable electronics |
| 5. | Copper | | Printed circuit boards (PCBs) and wiring for electronics |
| 6. | Gallium | | Semiconductors for high-frequency and microwave applications |
| 7. | Germanium | | Infrared optics and fibre optics |
| 8. | Graphite | ** | Conductive material in lithium-ion battery anodes |

| Sr. no. | Mineral/element | Import dependence | Use*** in ESDM sector |
|---|---|---|---|
| 9. | Hafnium | | Nuclear reactor control rods, microprocessors and high-temperature ceramics in electronics |
| 10. | Indium | | Indium tin oxide (ITO) coatings for touchscreens and displays |
| 11. | Lithium | | Rechargeable lithium-ion batteries for electronics |
| 12. | Molybdenum | | High-strength alloys for turbines, solar cells, semiconductor manufac-turing and as thin-film transistors |
| 13. | Niobium | | High-strength alloys and capacitors for electronic circuits and supercon-ductors |
| 14. | Nickel | | Rechargeable batteries, including nickel-cadmium cells |
| 15. | PGE | | Superconductors, electrical contacts and catalytic converters |
| 16. | Phosphorous | | Phosphors in fluorescent lighting, doping agent in semiconductor materials |
| 17. | Potash | | Not applicable |
| 18. | REE | | EVs, high-strength magnets and lasers |
| 19. | Rhenium | | High-temperature alloys, jet engines and electrical contacts |
| 20. | Silicon | | Photovoltaic cells and in integrated circuits (chips) and as a semiconductor material |
| 21. | Strontium | | Power generation for space vehicles, cathode ray tube (CRT) display glass |
| 22. | Tantalum | | Aerospace components, capacitors and high-power resistors in electronics |
| 23. | Tellurium | | Thermoelectric materials for power generation in electronics |
| 24. | Tin | | Soldering and solder alloys for electronic components |
| 25. | Titanium | | Electronic circuit hardware and as a structural material for electronic products |
| 26. | Tungsten | | Electrical contacts and light bulb filaments |
| 27. | Vanadium | | Aerospace communication systems and batteries such as vanadium redox flow batteries |
| 28. | Zirconium | | Nuclear fuel rods and corrosion-resistant alloys |
| 29. | Selenium | | Photovoltaic solar cells and glass manufacturing |
| 30. | Cadmium | | Cadmium telluride photovoltaic solar cells |

**Source:** Based on data from the Ministry of Mines, Government of India report

***Red:** 100% import dependence

****Yellow:** >50% import dependence

***Use in the sector is based on various sources. The list is non-exhaustive.

The Ministry of Mines report also mentions the countries which are heavily relied upon for certain minerals – China, Russia, Australia and South Africa feature prominently. The domestic critical minerals landscape highlights India's precarious position in global supply chains and the stark contrast in mineral security between India and well-established countries like China. India's limited reserves and production capabilities impact its industrial and technological sectors and also have broader implications for its economic and strategic autonomy. India's vulnerability in terms of access and control underscores the need for strategic international partnerships to secure its mineral needs. The following table provides a snapshot of the global distribution of key critical minerals for the ESDM sector.

**Table 3:** Known reserves of key critical minerals for the ESDM sector

| Mineral | Type of extraction | Known reserves in India (million tonnes) | Known reserves in China (million tonnes) | Largest-known reserves outside China (country) | Known reserves (million tonnes) |
|---|---|---|---|---|---|
| Lithium | Primary | 5.9 | 6.8 | Bolivia | 21 |
| Graphite | Primary | 8 | 52 | Turkey | 90 |
| Cobalt | By-product; co-product | - | 0.14 | Democratic Republic of Congo (DRC) | 4 |
| Niobium | Primary | - | 5.36 | Brazil | 16 |
| Tantalum | Primary; co-product | - | 0.18 | Australia | 0.099 |
| Gallium* | By-product | - | 0.75 | South Korea | 0.016 |
| Germanium** | By-product | - | 0.095 | Russia | 0.005 |
| REEs | Primary; co-product | 6.9 | 44 | Vietnam | 22 |

**Source:** Based on: PiB: https://pib.gov.in/PressReleseDetailm.aspx?PRID=1897799; US Geological Survey Mineral Commodities Summaries 2023: https://pubs.usgs.gov/periodicals/mcs2023/mcs2023.pdf

*Numbers listed indicate production capacity as quantitative estimates of recoverable gallium content in bauxite and zinc resources are not available

**Numbers listed indicate refinery production as quantitative estimates of recoverable germanium content in zinc and copper resources are not available

**The state of mineral reserves in India for selected elements have certain implications for global supply chains, some of which are discussed below.**

1. Lithium is a key component in batteries and renewable energy technologies which makes it vital to the green transition. The Lithium Triangle of Argentina, Bolivia and Chile holds 56% of the world's lithium reserves.[46] Bolivia has the largest reserves in the world at 21 million tonnes, but geographic and technological constraints have prevented mining operations in the country.[47] Despite relatively small reserves of its own, China controls lithium-related operations beyond its borders, including those in the Lithium Triangle, and accounts for over half the lithium refining capacity.[48] This makes it a central player with significant influence over the global supply chain. However, India's recent discovery of lithium reserves in Jammu and Kashmir makes it the seventh-largest reserve[49] in the world and gives it a significant boost towards autonomy. In future, carrying out scoping exercises may lead the country to discover more hidden reserves. There is also the possibility that these reserves will help us develop the initial processing capacity for lithium, if leveraged correctly.

2. Graphite is essential for its use in lubricants, refractories and batteries. It presents significant disparity as India's graphite reserves are modest at 8 million tonnes, while China's reserves are significantly larger at 52 million tonnes. The largest-known reserves, however, are in Turkey, with 90

46 https://www.cepal.org/en/pressreleases/eclac-stresses-importance-productive-development-agenda-centered-lithium-exploitation

47 https://www.reuters.com/world/americas/bolivia-seals-14-bln-lithium-deals-with-russias-rosatom-chinas-guoan-2023-06-29/

48 https://www.orfonline.org/expert-speak/implications-of-lithium-reserves-in-jammu-and-kashmir

49 https://timesofindia.indiatimes.com/india/5-9-million-tonne-find-in-jk-makes-india-7th-largest-resource-of-lithium-in-world/articleshow/97809105.cms?from=mdr

million tonnes, thus highlighting Turkey's strategic importance in the graphite industry. India has the potential to actively scout Turkey as a partner given its close ties with other countries in the region.

3. Cobalt, primarily used in battery production and superalloys, is one of the significant minerals of which India has no known viable reserves. The DRC stands out with 4 million tonnes, underscoring its dominance in the global cobalt market.[50] Partnership building in the African continent is already a policy position the Government. Targeted partnerships with preferential trade agreements or memorandums of understanding in the critical minerals space would be important for India to acquire these minerals.

4. Niobium is a key mineral used to make the strongest-known magnets on Earth. While there are no known reserves in India, China has a significant presence in the market with reserves of 5.36 million tonnes.[51] Brazil, with 16 million tonnes, is the most significant player.[52] However, China's recent claims of discovering the world's largest, rare-earth deposit of niobium in Inner Mongolia may change the global landscape.[53] Therefore, India needs to ensure that ties with Brazil remain cordial. Moreover, it is the right time to have a look at the India-MERCOSUR Preferential Trade Agreement (PTA), which will help in gauging and enabling more strategic partnerships.

5. Tantalum is used in electronics, capacitors, and superalloys. Outside of China and Australia, tantalum is found in African countries including the DRC, Colombia, Rwanda, Ethiopia and Mozambique in limited quantities. However, we should account for the fact that China may be the biggest shareholder in the mines in these regions. India must, therefore, aim to get ahead of this trend by encouraging investments both through public and private routes.

6. Gallium and germanium, crucial elements in both semiconductors and LEDs, are the by-products of mining other minerals. Gallium is recovered while processing bauxite and zinc, and germanium while processing zinc and copper. Their extraction has a significantly negative impact on the environment. This makes resource estimation particularly difficult and gives established producers like China an added advantage. Given that gallium is posited as a replacement for silicon, it is truly a mineral of the future and, therefore, better ways to process gallium must be prioritised. Currently, India faces a knowledge gap in that it can only produce gallium by having access to the right technology and correctly processing bauxite and zinc.

7. Finally, for REEs, which have a key role to play in numerous high-tech and clean-energy applications, India has significant reserves at 6.9 million tonnes.[54] While being significantly less than China's 44 million tonnes, these reserves still place India at the fifth position in terms of world ranking[55] and give it the much-needed leverage in the market. Here too, we need to ensure that our processing technology is such that leakages are reduced.

50 https://pubs.usgs.gov/periodicals/mcs2023/mcs2023.pdf

51 https://www.sciencedirect.com/science/article/pii/S0169136823003189#:~:text=It%20is%20urgent%20to%20make,et%20al.%2C%202019

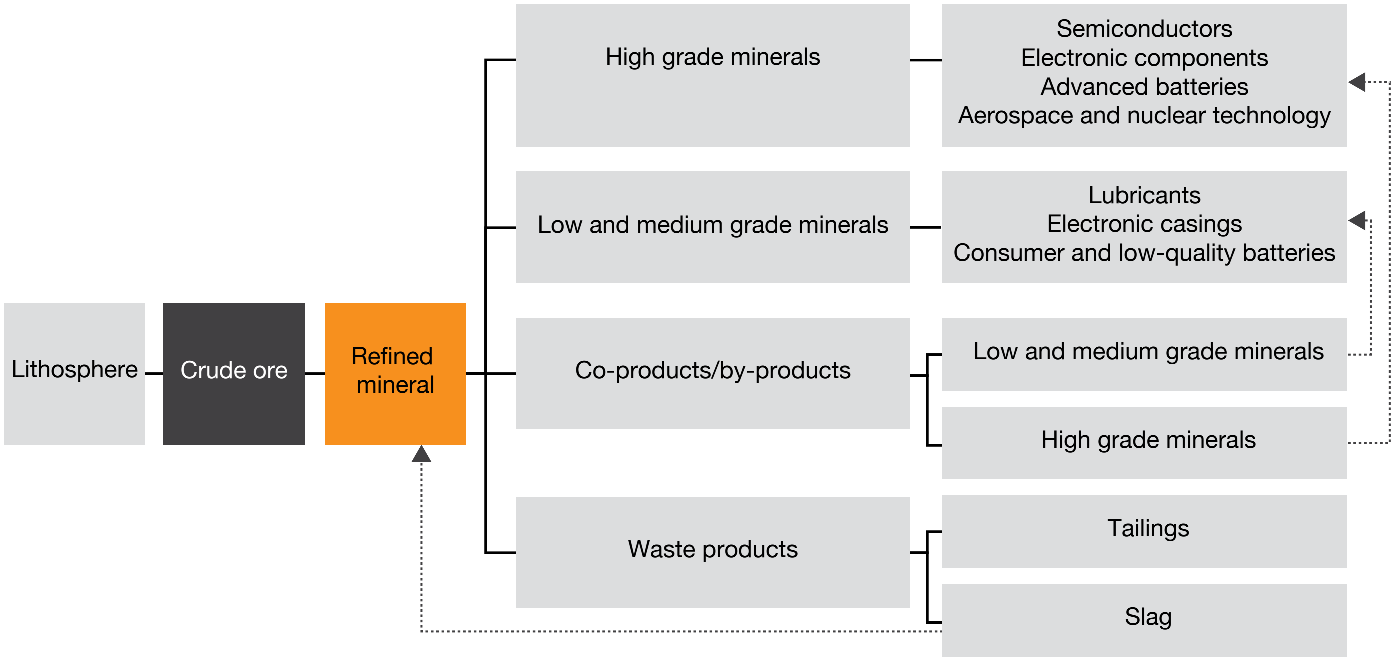
52 https://pubs.usgs.gov/periodicals/mcs2023/mcs2023.pdf

53 https://www.scmp.com/news/china/science/article/3237118/it-could-make-china-self-sufficient-new-strategic-rare-metal-ore-unearthed-inner-mongolia

54 https://pubs.usgs.gov/periodicals/mcs2023/mcs2023.pdf

55 https://pib.gov.in/PressReleasePage.aspx?PRID=1914305

**Figure 8: Indicative critical mineral industry chain**




**Source:** ORF analysis

Whether analysed through the perspective of the critical mineral value chain or industry supply chain, it is evident that the journey from raw materials to finished products is not straightforward. Differences also arise from the nature of each element or mineral, their processing methods, and storage and transport requirements.

Each branch of the chain performs a specific function that can be impacted by either geographical or technological changes. While geographical bottlenecks are harder to overcome, technological advancements can unlock new opportunities for India to secure its role in these supply chains.

To capitalise on the advantage India already possesses in electronics manufacturing and new green technology sectors, India needs access to reliable supplies of critical minerals. This vulnerability can only be addressed by ensuring a diversity of partners from whom these minerals can be sourced. Another solution would be to invest in R&D to find close substitutes for these products. We must also acknowledge that resilience in electronics supply chains will not be possible without securing sources of these raw materials – even as we build the processing capacity in-house to ensure that we move up the value chain.

## Securing potential

When it comes to ESDM manufacturing and securing critical supply chains, India must leverage its available reserves of minerals, such as REEs, to facilitate access to the resources it lacks. This not only includes FTAs but also capacity building to move up the value chain and maximise returns from the available raw materials. For minerals that are scarce in India and imported from other countries, India needs to ensure cordial ties with politically stable countries to fulfil its commodity needs. Moreover, it needs to take prompt action to shift its supply dependence away from countries like China which may leverage its supply chain dominance for political gain.[56]

Due to the availability of cost-effective deposits and refining capacities, the three largest mineral-

56 https://www.nytimes.com/2010/09/23/business/global/23rare.html

producing countries account for about 70% of mineral commodities.[57] For instance, in 2022, the three largest exporters of REEs (HS280530) were China, Thailand and Japan according to the International Trade Centre's Trade Map.[58] China accounted for approximately 393 million tonnes of exports while Japan accounted for 20 million tonnes.[59]

For India to have a diversified supply to hedge geoeconomic risks, it needs to pursue multiple policy options. In order to do that, India needs to focus on building its own capacities as well as trade relationships with like-minded partners. Table 4 highlights the strategic options for stabilising and strengthening India's critical mineral resource supply chains.

**Table 4:** Strategic recommendations for India to improve access to critical minerals

| Mineral | Country/grouping | Type of trade agreement | Significance |
|---|---|---|---|
| Lithium | Argentina, Chile | Bilateral agreements | India has already established relationships with Argentina and Chile. It needs to make these partnerships more substantial through trade agreements and establish a relationship with Bolivia once mining becomes viable in the country. India already has a PTA with Argentina through MERCOSUR and with Chile bilaterally. |
| | Australia | CEPA | India has the potential to forge a more comprehensive agreement with Australia that includes tech transfers for India to mine its own lithium since both countries have hard rock reserves. There is also potential for collaboration on sustainable mining practices. |
| Graphite | Turkey | Bilateral agreement | There are significant mutual benefits to be gained from graphite imports by India and REE imports by Turkey. While we already have customs and double taxation avoidance agreements, perhaps a targeted agreement with Turkey on specific sectors – if not an FTA – would help obtain better trade benefits. |
| Cobalt | DRC | Bilateral agreement | India already has a forum for discussing trade issues with Southern African Development Community (SADC) members of which Congo is a part. However, it might be in our interest to encourage a bilateral investment or trade treaty to secure critical mineral supply chains. Technology transfer should be a key component here to ensure that there is no extractive tendency in these agreements, thus establishing India as a more reliable development partner. |
| Niobium | Brazil | Bilateral agreement | Given the number of MERCOSUR members with mineral reserves, it is in India's interest to update the India-MERCOSUR FTA. |
| Tantalum | African Union | Multilateral agreement | A trade agreement with the African Union would facilitate partnerships with resource-rich countries like the DRC, Rwanda, Ethiopia and Mozambique. |

57 https://www.imf.org/-/media/Files/Publications/WEO/2023/October/English/ch3.ashx

58 https://www.trademap.org/Country_SelProduct.aspx?nvpm=1%7c%7c%7c%7c%7c280530%7c%7c%7c6%7c1%7c1%7c2%7c1%7c%7c2%7c1%7c%7c1

59 https://mas-admintools.intracen.org/accounts/TermsConditions.aspx

| Mineral | Country/grouping | Type of trade agreement | Significance |
| --- | --- | --- | --- |
| Gallium | Japan and South Korea | Specific partnerships | India already has FTAs with both of these countries. However, specific partnerships for technology transfer to India could be encouraged, which would also enable it to become a more reliable source of gallium for these partners. |
| Germanium | Canada, Finland and the US | Bilateral agreements | China and Russia's dominance in the market makes it vital to establish more reliable avenues for supply. |
| REEs | Vietnam | Technological partnerships | India and the Association of Southeast Asian Nations (ASEAN) already have an FTA that can be leveraged. However, specific partnerships between the public and private sectors of the two countries should be encouraged given that Vietnam is a reliable Southeast Asia partner. |

In today's rapidly evolving geopolitical climate, value chain vulnerabilities have a direct impact on commodity pricing in critical minerals markets. Since 1996, there has been a significant shift towards global macroeconomic shocks being the main source of commodity price volatility.[60] This transition from specific supply shocks within individual markets to broader economic trends profoundly impacts critical minerals. Furthermore, it has led to excessive concentration of markets and an oligopolistic minerals ecosystem. This could result in under-investment and overpricing of the clean energy transition[61] in addition to the impact on the digital economy. Fragmentation in minerals markets further compounds pricing problems. This fragmentation can occur due to concentrations in either the first or second stage of production. The first production stage of commodities relies on natural endowments, and the second stage consists of processing. As commodity production is related to the natural geographic occurrence of minerals, it makes the relocation of production considerably difficult. These minerals also do not have adequate substitutes which can be used in the production process for the short term. Gallium and silicon, for instance, are used in semiconductors due to their transmitting capacity, the technology for which has taken decades to perfect using these elements.

## Steps to resilience

The derivatives markets for critical minerals play a crucial role in price discovery and risk management for processors, miners, financiers and other stakeholders.[62] Indian commodities exchanges (commexes) are currently trading in aluminium, copper and nickel.[63] However, there needs to be more product innovation and capacity building for creating adequate traction among the stakeholders in the critical minerals ecosystem. There is a significant supply-demand imbalance as regards access to and refining processes of critical minerals. One aspect of India's strategy should involve building international partnerships with countries that have abundant reserves of these critical minerals.

A broader strategy that the country has deployed has been using the public sector to establish international partnerships. India established Khanij Bidesh India Ltd (KABIL), a joint venture between three public sector companies – National Aluminium Company Ltd. (NALCO), Hindustan Copper Limited (HCL) and Mineral Exploration and Consultancy Limited (MECL) – aimed at identifying and acquiring overseas mineral assets. KABIL currently has engagements underway with Australia, Argentina, Bolivia and Chile to explore possibilities of mineral asset acquisition.[64] India also joined the Minerals Security Partnership, a collaboration of 13 countries

60 https://blogs.worldbank.org/developmenttalk/commodity-price-cycles-causes-and-consequences

61 https://www.imf.org/-/media/Files/Publications/WEO/2023/October/English/ch3.ashx

62 https://unctad.org/system/files/official-document/ditccom20089_en.pdf

63 https://www.sebi.gov.in/sebi_data/faqfiles/feb-2024/1706788568782.pdf, Pg. 4

64 https://mines.gov.in/admin/storage/app/uploads/6433da09a9f741681119753.pdf

and the EU to catalyse public and private investments in responsible critical minerals supply chains globally.[65]

However, a wider view of potential partner countries is necessary. Although partnerships with countries in Africa remain underexplored, they could benefit from taking a cue from China and the countries in Europe. This would mean securing the supply chain by making purposeful investments in foreign mines.

A trade deficit with countries lower down in the value chain can be offset by using these raw materials to produce high-value outputs. For example, recognition of supply chain vulnerabilities led to the introduction of the joint industrial policy,[66] which enables states to share their industrial strategies at the international level and build supply chains collaboratively. The key to forging meaningful relationships will, therefore, lie in identifying what India can provide that aligns with the partner countries' vision for themselves in global supply chains.

It is important to note that access to raw materials is not enough to secure value chains. Processing technology, in the absence of natural endowments, is essential. From the US's chip war to China's restrictions on solar inputs,[67] access to technology is increasingly becoming the new economic battlefield. Countries that have the capability to process critical minerals and convert them into high-value components and products, like semiconductor chips or advanced batteries, stand to gain significantly. As such sophisticated technology, required for refining minerals and manufacturing products, is yet to be developed in India, technology transfers can become a powerful tool to boost India's capabilities and improve R&D, innovation and human capital development in the country.

The US has emerged as an important partner in this endeavour, with the US–India initiative on Critical and Emerging Technology (iCET)[68] forming the cornerstone of a strategic alliance. The iCET aims to expand the strategic technology partnership and defence industrial cooperation between the two nations, with one of its focus areas being semiconductor supply chains. India can also leverage its strong bonds with countries like Australia that have similar reserves to import the hard skills and technologies required to capitalise on its resources.[69]

There are numerous parallels and downstream impacts of critical mineral supply chains on the ESDM ecosystem. The next chapter discusses the larger picture of ESDM production and the issues and opportunities it presents.

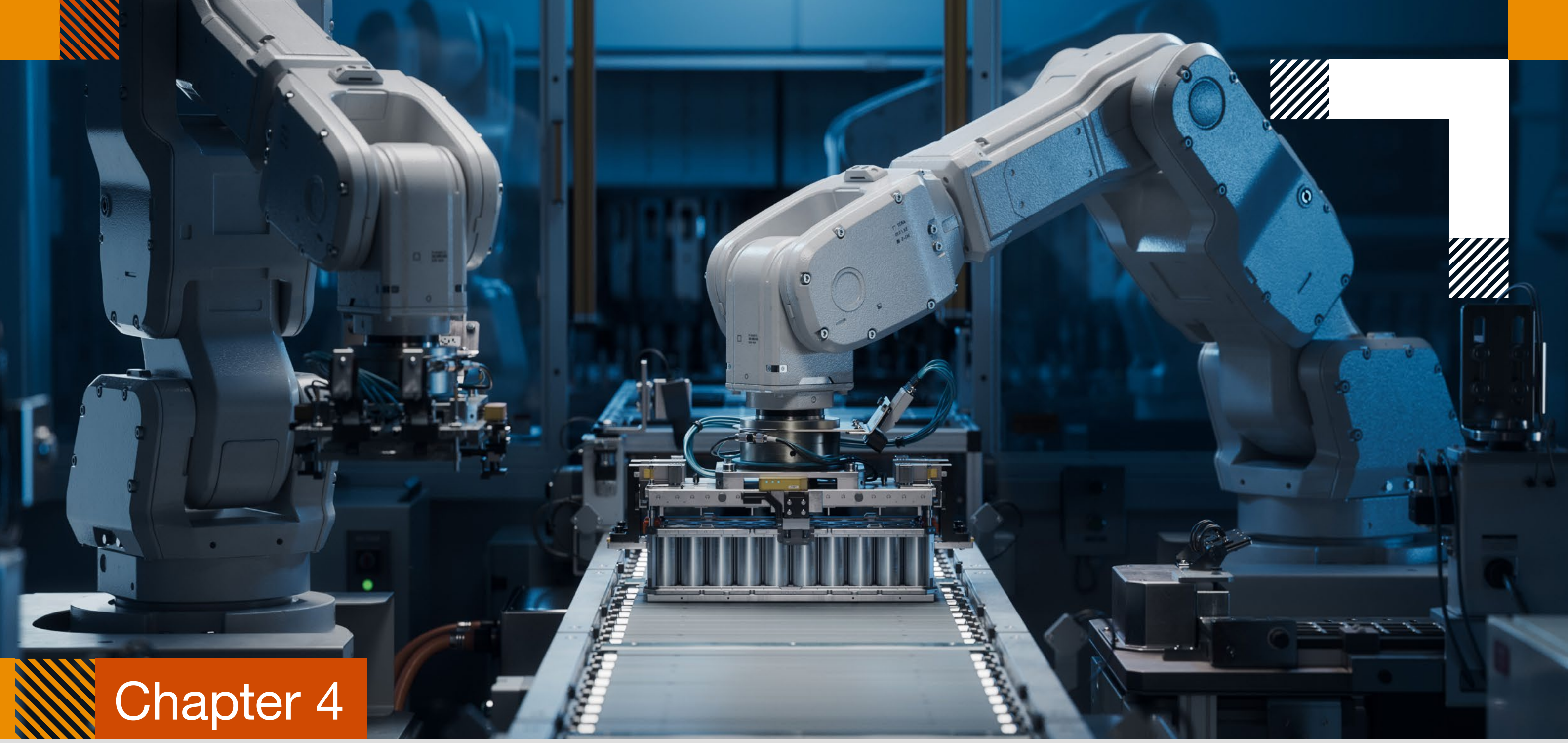
65 https://www.state.gov/minerals-security-partnership/

66 https://carnegieendowment.org/2023/05/03/friendshoring-critical-minerals-what-could-u.s.-and-its-partners-produce-pub-89659

67 https://www.reuters.com/breakingviews/china-ban-would-slow-not-halt-western-solar-push-2023-02-03/

68 https://www.whitehouse.gov/briefing-room/statements-releases/2023/01/31/fact-sheet-united-states-and-india-elevate-strategic-partnership-with-the-initiative-on-critical-and-emerging-technology-icet/

69 https://www.orfonline.org/expert-speak/implications-of-lithium-reserves-in-jammu-and-kashmir#:~:text=In%20February%202023%2C%20the%20Geological,largest%20source%20of%20lithium%20globally.



Chapter 4

# Ecosystem analysis

The Indian electronics industry is progressing towards realising its potential in production, service and design capacity. However, further progress will only be possible if we are proactive in identifying the gaps and ensuring stable regulations to boost the sector. Therefore, in order to reach the industry's potential, it is necessary to build a holistic ecosystem that will help in enhancing production and service competitiveness.

## Design challenges

Terms like 'onshoring', 'nearshoring' and 'friendshoring' have become buzzwords in the policy space when ideating methods to secure critical value chains. India has taken steps towards onshoring major parts of the ESDM sector not only due to its growth potential but also because of the impact it has on day-to-day lives and livelihoods.

At this stage, it is important for the country to acknowledge domestic limitations due to geographic realities or its current position in the development spectrum. The economic reality of India having jumped from the primary to tertiary services sector without adequately developing the manufacturing sector continues to impact Indian manufacturing. In the last 20 to 30 years, we have seen concentrated efforts by successive governments to course correct. It was only in the last decade, however, that we saw the private sector rise up to the challenge. This has been made possible due to a full ecosystem of policies that has been steadily developing where the FDI rules are in sync with industrial policy. Investment in sectors where India aims to improve its value chain position should be made easier. Moreover, both ESDM and mining sectors allow 100% FDI via the automatic route.

## Technology access: Necessity and innovation

An important element that often gets missed in the supply chain conversation is access to processing and production technology. More efficient methods tend to elude the Global South due to strict IP regimes and non-tariff methods to block competition and thus innovation. India has been in a unique position vis-à-vis this issue, as the country has large innovation labs and R&D gets supported more than most other countries. As of 2023, we have the seventh-highest global spend on R&D at

65.2 billion but this accounts for only 0.65% of our GDP and is well below the 3–4% of GDP ratio that other large economies maintain.[70] Engineering and related sectors contribute to a large part of this innovation spend.[71] However, this support continues to be in the realms deemed more strategically important to the Government – with limited resources. Targeted public spending on new technologies and acquiring IP rights is not getting enough attention in spite of this. Therefore, closing the IP gap is an important issue of the ESDM value chain ecosystem that must be addressed.

## The skilled labour conundrum

The expansion of the ESDM sector extends beyond mere trade – it has a direct impact on livelihoods across a broad spectrum. A booming industry usually implies the generation of more jobs. Expanding the ESDM sector will potentially offer a diverse range of employment opportunities, spanning from the initial stages of mining critical minerals to high-tech manufacturing.

However, in order to ensure sustained growth of the industry, it is essential that a multi-skilled labour pool is available. Presently, the absence of this has caused low employment of new workforce entrants. Another salient hurdle is the underwhelming technical competence. Most of the new production facilities need niche skills and computer knowledge, both of which are not adequately present in the workforce. The ability of workers to adapt promptly to novel technologies is also significantly low. Inadequate soft skills reduce hiring prospects, with the industry becoming increasingly global. Insufficient verbal and written communication skills are some shortcomings, with the increasing number of customer touchpoints the sector is witnessing. Assuming a constant ratio of market size to a digitally skilled employee base, the anticipated doubling of the internet of things (IoT) market size in India by 2025 would require a simultaneous doubling of its digitally skilled employee base to 28,00,000 from the current 14,00,000.[72]

Further, women are gradually gaining prominence for electronics companies that are looking to tap into the Indian talent pool as women's participation in this sector is increasing. This bodes well for firms that will have to improve their hiring processes to increase the share of domestic production for the country's USD 155 billion electronics market beyond the current 65%. However, supporting women's contribution as part of the workforce requires companies to prioritise their security and working conditions by customising their workspaces accordingly. Provision of dormitories for outstation employees as well as periodic visits by environment, health and safety department, and the employee relations team would be helpful in this regard, and seems to have been implemented by some companies.[73]

Most workers encounter financial limitations to self-learning, particularly migrant labour from rural areas in the services segment. The industry, moreover, lacks training institutes and finishing schools focussed on quality training for installation, services and repairs. A significant divergence exists between academic courses and the practical skillset needed. Table 5 shows the sub-sector wise percentage of employees engaged in services, design and manufacturing.

70 https://www.thehindubusinessline.com/data-stories/visually/indias-rd-needs-a-boost/article67198927.ece

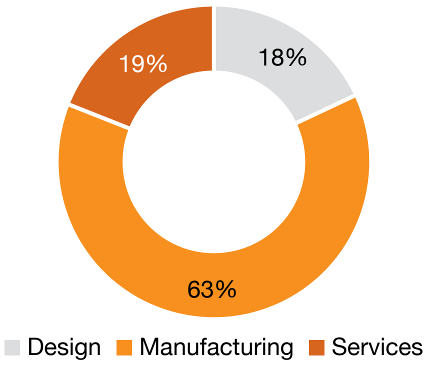
71 https://dst.gov.in/sites/default/files/R%26D%20Statistics%20at%20a%20Glance%2C%202022-23.pdf

72 https://www.pwc.in/research-and-insights-hub/india-calling-decoding-the-countrys-electronics-manufacturing-journey-and-the-way-forward.html#sources

73 https://economictimes.indiatimes.com/tech/technology/in-depth-indias-lofty-electronics-manufacturing-ambitions-rides-heavily-on-young-women/articleshow/106237268.cms

**Table 5:** Important skills needed by six sub-sectors of India's electronics industry

### PCB design and manufacturing

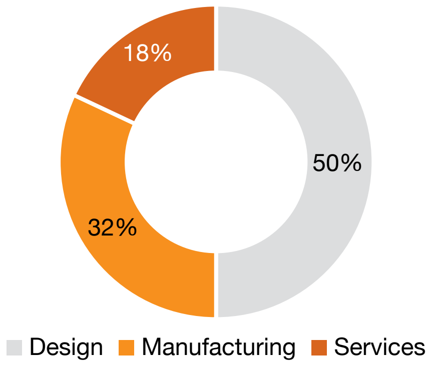



**Design:** Library accuracy, signal behaviour, power integration, thermal analysis, experience of various tools

**Manufacturing:** Practical knowledge of machine operations like mechatronics, electroplaters, fitters, circuit routing, schematics

**Service:** Mechanical drafting, electronic structuring, electronic fabrication, laboratory courses.

### Semiconductors and components

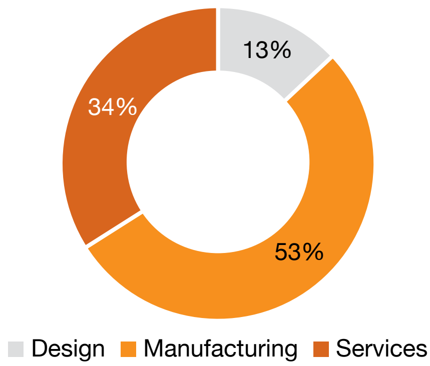



**Design:** Library development, component location on PCB, component identification, specification

**Manufacturing:** Knowledge of circuit boards, processors, chips, electronic equipment, and computer hardware and software.

**Service:** Technical knowledge of components, repair services like soldering, component handling, etc.

### E-Mobility and battery

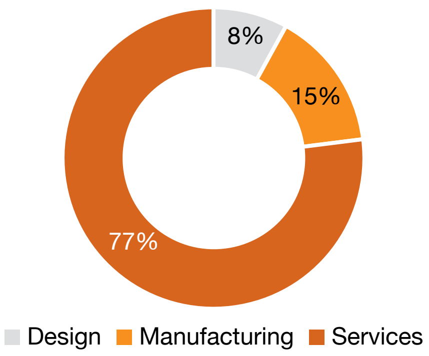



**Design:** Battery management, battery safety, battery and charging system design, drive-train (motor, transmission, invertor)

**Manufacturing:** Li-ion batteries, expertise, EV power train, battery performance analysis, testing and debugging, validation

**Service:** Electric vehicle charging, packaging and transportation of Li-ion batteries, troubleshooting, electrical power cabling

### Solar and LED

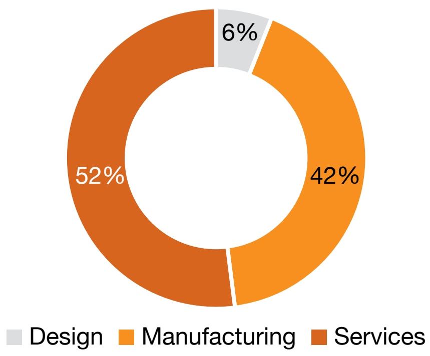



**Design:** Knowledge of RE screen software, HeliScope, site analysis, 2D/3D design, LED efficiency (Lumens)

**Manufacturing:** Testing of PV modules, solar packaging, electrical measurement, soldering techniques

**Service:** Solar panel repairs, wiring and installation, basic knowledge on installation of floating solar, LED repairs

### Security and surveillance

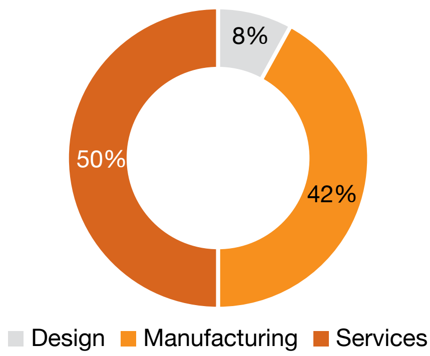



**Design:** Circuit design, logic gates, MATLAB design, advanced mathematics, tools like C++ and LabVIEW

**Manufacturing:** Knowledge of safety aspects in manufacturing, digital control systems, bio-medical instrumentation, etc.

**Service:** Troubleshooting, assembling and disassembling, repair and monitoring of alarm systems, CCTV systems

### Industrial automation




**Design:** General assembly drawings (GAD), PLC and HMI programming, control system design, process automation

**Manufacturing:** Product validation and verification, reliability testing, ability to use various machines and hand tools

**Service:** Preparation of the budget, EHS management, Industry 4.0, IoT and smart factory, lean manufacturing

**Source:** Ministry of Skill Development and Entrepreneurship[74]

74 https://skillsip.nsdcindia.org/sites/default/files/kps-document/A%20Study%20to%20Assess%20Employment%20Potential%20%26%20Skilling%20Requirement.pdf

## Addressing the skills gap

The industry's initiatives to mitigate the existing skill gaps can be broadly classified into the following three categories:

**Traditional training and initiation:** Trainers travel to various locations where group or team leaders are congregated, and training is provided.

**Niche training:** This is primarily meant for mid-level workers like engineers and senior technicians trained at the company's training centres.

**Ad-hoc upskilling:** This is targeted primarily at the senior management and comprises online courses and on-site international training as and when required.

**Table 6:** An overview of some skilling programmes underway in India

| | |
|---|---|
| **PCB design and manufacturing** | • Private sector companies are training diploma holders and graduate engineers on tools like computer aided manufacturing (CAM), computer aided design (CAD), design library, printed circuit boards (PCB) layout, etc. by visiting their institutes.<br>• A leading telecom firm in Bangalore has signed on MoU with Telecom Sector Skill Council (TSSC) to promote and develop telecom skills across students, technicians, and ITI diploma holders. |
| **Semiconductors and components** | • Institutes training diploma holders are working with National Skill Development Corporation (NSDC) for skill development, even on latest technologies like IoT, deep learning, artificial intelligence, etc.<br>• A technology firm in India has opened an in-house training centre which imparts training on skills including integrated circuit design software (ICDS), electronic design automation (EDA), Internet of Things (IoT), field-programmable gate array (FPGA), and embedded programming.<br>• The world's leading processor manufacturer has trained more than 1,00,000 students and developers for AI in India.<br>• A leading semiconductor manufacturer from Germany has tie-ups with NSDC to provide training on semiconductors and chip technology. |
| **E-Mobility and battery** | • Indian institutions have become skill partners for NITI Aayog Electric Vehicle Mobility Vision 2030.<br>• A Canadian online resource start-up, has started an India-specific programme on electric vehicle battery and Battery Management System (BMS) masterclasses. |
| **Solar** | • One of India's leading solar systems manufacturer is imparting skill training through their own skill development institute.<br>• A global solar system design and manufacturing firm has tied-up with NISE (National Institute of Solar Energy) to train ITI diploma holders and attain Suryamitra certification.<br>• A leading Indian manufacturer is providing training at the Solar Skill Training Centre, Karjat, and have trained around 775 students so far in various programmes.<br>• Another major Indian solar systems manufacturer has adopted the Industrial Training Institute (ITI) at Bahal under Public-Private Partnership to upgrade it into a centre of excellence (BRCM Skill Development Training Centre). |
| **LED** | • A Netherland-based global LED manufacturer is offering a range of educational resources like webinars and online courses to expand knowledge on lighting, along with an LED certification programme.<br>• A major Indian fan and light manufacturer has come forward to provide vocational training to enhance employability. Their state-of-the-art electrical skill center at Pusa ITI provides industrial training to youth. |
| **Security and surveillance** | • A global automation brand with presence in India has a separate wing which trains people on various technologies to meet the global standards.<br>• A Hangzhou based company with presence in India has launched an 'Integrated Partner Programme' which trains participants in skills including technical support, SKD training, integration support, co-marketing, etc.<br>• A US-based global controls manufacturer runs its own institute for heating, ventilation, and air conditioning (HVAC) which partners with colleges, institutes, and experts from building industry to provide a high-quality practical training.<br>• A Tirupati-based Indian firm conducts a government-approved training initiative on surveillance technologies and offers hands-on experience of all types of security solutions and equipment. |
| **Industrial Automation** | • An NSDC-affiliated company runs courses in industrial automation, building automation, MATLAB, embedded systems and LabVIEW.<br>• An Indian firm provides training on topics such as PLCs, SCADA, VFD, HMI, wiring of PLC, panel designing, relays, contactor, PID, sensors and electrical CAD.<br>• A leading training institute in India is also imparting courses on cutting-edge industrial automation technologies to fresh engineering graduates and diploma holders. |

**Source:** Ministry of Skill Development and Entrepreneurship: https://skillsip.nsdcindia.org/sites/default/files/kps-document/A%20Study%20to%20Assess%20Employment%20Potential%20%26%20Skilling%20Requirement.pdf

**Despite these strategies, several measures need to be implemented to enhance India's capacity in the global value chains. These measures must include the following aspects:**

**Expanded vocational training and education:** India needs to expand its network of vocational training centres and educational institutions, while focusing on improving the electronics manufacturing skills of its workforce. Partnerships between industry and academia can ensure that the curriculum is aligned with industry needs, providing practical, hands-on experience. For instance, Germany's dual education system, which combines apprenticeship in a company and vocational education at a vocational school, can serve as a model.[75]

**Government and industry collaboration:** The Government can accelerate collaborations with the electronics industry to identify and forecast future skill requirements. Initiatives like 'Skill India' can be tailored more precisely for the electronics sector, ensuring that training programmes are up-to-date and relevant. Such collaborations can also help establish more finishing schools and training institutes focussed on niche skills.[76]

**Leveraging technology for training:** Technology, particularly online learning platforms, can be pivotal in upskilling the workforce. Massive open online courses (MOOCs) and virtual reality (VR) training environments can provide scalable and cost-effective solutions for technical training.[77] Using AI to create personalised learning paths can enhance the effectiveness of these training programmes.

**Financial support and incentives for training:** To address the financial barriers faced by migrant workers and the underprivileged in accessing training, the Government and related industries can provide scholarships, subsidies and financial incentives. This would encourage more individuals to pursue training in specialised electronics skills.

**Promoting soft skills development:** Given the global nature of the electronics industry, there's a need to integrate soft skills training, such as communication and teamwork, into technical training programmes. This will ensure that the workforce is technically competent and can effectively engage in a global environment.[78]

**Creating a responsive education system:** The education system should be dynamic, adapting quickly to the evolving demands of the electronics industry. Continuous feedback loops between industry and educational institutions can ensure the curriculum remains relevant and up-to-date.[79]

**International collaborations and exchange programmes:** Building international partnerships and exchange programmes can provide exposure to global best practices and standards in electronics manufacturing. This would improve the workforce's skill set and integrate the Indian electronics sector more closely with the global value chain.

**Regular industry assessments and feedback:** Regular industry assessments and feedback are deemed essential for the timely identification of skill gaps and areas requiring improvement.[80] An important step involves conducting a skill-gap analysis to evaluate the current workforce's capabilities and identify discrepancies. Moreover, it would be beneficial to consistently review assessment results and swiftly adjust training programmes to ensure ongoing relevance and effectiveness. Additionally, establishing effective feedback mechanisms involving industry stakeholders, employees and trainers is crucial to gather diverse perspectives on skill needs in the electronics sector.

## Bridging ecosystem gaps through policy interventions

The policy ecosystem in India has evolved considerably and can be leveraged to bridge some of the gaps that have been identified within the ESDM ecosystem – specifically around the electronics manufacturing value chains – to make India a global manufacturing hub. In this section, we will focus on the macro-policies at the central level that kickstarted the transformation of electronics manufacturing by inviting global supply chains to localise some parts in India. Moreover, we will

75 https://www.make-it-in-germany.com/en/study-training/training-in-germany/vocational/dual-system
76 https://www.essc-india.org/
77 https://www.intechopen.com/chapters/1124046
78 https://www.ilo.org/wcmsp5/groups/public/---dgreports/---inst/documents/publication/wcms_646038.pdf
79 https://tech.ed.gov/files/2017/01/NETP17.pdf
80 https://www.degruyter.com/document/doi/10.1515/eng-2020-0072/html?lang=en

look at how an element of competitive federalism has been ushered into the country to support several state-level policies to cater for any policy blind spots or niche challenges that may lead to operational disabilities for manufacturing enterprises in the state. Furthermore, we will identify Indian states that have been performing well and elaborate on the policies related to land, electricity and labour, which have played a key role in attracting international players and improved India's self-reliance in electronics.

The combination of central policies along with targeted state-level incentives to offset operational disabilities is expected to catalyse the growth and development of electronics manufacturing and ESDM value chains in India.

## Tracing the policy evolution – from M-SIPS to PLI[81]

India's policy paradigm for catalysing electronics manufacturing and ESDM value chains is not exactly a new endeavour. It has been an ongoing process since the early years of the last decade. During that period, the Indian electronics industry encountered a wide demand-supply gap with high import dependency, a complex tax structure, limited quality industrial infrastructure, staggered logistics and poor last-mile connectivity, inflexible labour laws, limited R&D focus, and negligible value addition. The multi-dimensional challenges of the electronics industry thus necessitated the Government to undertake a holistic approach that could mitigate these challenges.

In 2012, the first National Policy on Electronics (NPE) was implemented. It was designed to be a multi-faceted approach to offset the shortcomings of the Indian electronics industry. Under this, schemes such as M-SIPS and Electronics Manufacturing Clusters (EMC) Scheme, Phased Manufacturing Programme (PMP) and Electronics Development Fund (EDF) Policy, were introduced. These policies were further boosted under the aegis of Make in India and Digital India initiatives by the Government to boost national manufacturing in the electronics sector.

In 2016, the GoI followed the policy paradigm with a phased roadmap to promote domestic manufacturing of mobile phones in India. The choice of mobile phone was, perhaps incidentally, aligned with the GoI's movement to implement the Jan Dhan-Aadhaar-Mobile (JAM) trinity, which was envisioned to become the primary interface between citizens and the Government. During this phase, the GoI's PMP notified a 12.5% countervailing duty on imports and a 1% excise duty without input tax credit for domestic companies manufacturing mobile phones.[82] Simultaneously, basic customs duty was exempted for parts, components and accessories. These became the initial stepping stones for global manufacturers to anchor low-value and high labour-intensive activities of the electronics value chain to India – primarily activities related to final product and component assembly.

81 https://www.pwc.in/assets/pdfs/india-calling-decoding-the-countrys-electronics-manufacturing-journey-and-the-way-forward/india-calling-decoding-the-countrys-electronics-manufacturing-journey-and-the-way-forward.pdf

82 https://www.meity.gov.in/writereaddata/files/Notification_PMP_Cellular%20Mobile%20Handsets_28.04.2017.pdf

**Figure 9: Evolution of the policy paradigm – making electronics in India**

**2012**

| Modified Special Incentive Package Scheme (M-SIPS) | National Policy on Electronics (NPE) | Electronics Manufacturing Cluster (EMC) Scheme | Phased Manufacturing Programme (PMP) |
|---|---|---|---|
| To offset disability and attract investments in ESDM Industries | Provided a roadmap for the development of electronics sector in India | To provide world-class infrastructure for attracting investments in the ESDM sector | To promote domestic manufacturing of mobile phones with a differential excise duty dispensation |

**2014** → **2015**

| 'Make In India' initiative | Digital India and Skill India initiatives | Electronics Development Fund Policy |
|---|---|---|
| Devised to transform India into a global design and manufacturing hub | Large-scale digital adoption triggered by government efforts<br>Provides 75% to 100% of training cost for industry specific skills in the electronics sector. | Provides risk capital to companies developing new technologies in electronics, nano-electronics and IT |

**Source:** PwC analysis

In 2019, the Government further revamped the existing policy and called it NPE 2.0, which adopts a more integrated approach to build India's capacity in core technology. NPE 2.0 also incentivised capital expenditure (Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors) to offset sunk costs in the manufacturing sector and promote the development of world-class industrial and capital infrastructure in India. The GoI also focused on improving the scale of production in India through the implementation of PLI and expanded the scope of the EMC scheme for supporting new-age infrastructure for electronics manufacturing. These new developments were complemented through extensive skill-development initiatives across the electronics manufacturing value chain, such as Skill India, for adequate training in market-relevant skills, designing of special curriculum with industry experts for students, extension of financial incentives to private sector players in order to reduce costs, and establishment of institutions through public-private partnerships to create an industry-ready workforce.

**Figure 10: Three-pillar approach of the GoI in policy development**

| Fiscal | Infrastructure | Skill development |
|---|---|---|
| **National Electronics Policy** – Roadmap for the electronics sector | **Gati Shakti** Integrated planning of infrastructure projects | **Skill India** |
| **PLI –** Large scale and telecom equipment **and PMP** | National Infra Pipeline **9000** Projects and USD **2 trillion** outlay | **Designing curriculum** with industry experts for students |
| **SPECS** - capital subsidy for semiconductor manufacturing | **EMC** – Creation of sector-specific Infrastructure | **Financial incentives to** reduce cost of skilling |
| **Semiconductor programme –** Fiscal support for fab, display, design | **DFCs and ICS** - to strengthen the logistics and industrial ecosystem | **Formulation of PPPs** to create **industry ready workforce** |
| **State level incentives** by different state governments | | |

**Source:** PwC analysis

## Solving the capital infrastructure challenge

A good policy design is one that can be seamlessly implemented through responsive institutions. While all operational factors were being systematically addressed for projecting India as an electronics manufacturing hub, the most crucial challenge of lacking quality industrial infrastructure – similar to those of Vietnam and Thailand – still remained. Given the high capital-intensive nature of electronics manufacturing, the Government's M-SIPS scheme provided incentives to the tune of 20–25% on capital expenditure to electronics manufacturing – including those manufacturing smartphones and their ancillaries. The major benefit of the scheme was its targeted implementation for products such as mobile phones, telecom equipment, IP-based new-generation soft switches/routers, data networking equipment, transport systems, cross-connections, radio over fibre, carrier ethernet, wireless technology as well as distributed antenna systems. Therefore, the capital infrastructure gap was not only bridged for the finished product, but also for its constituent components. This helped in making the ecosystem sustainable and competitive in manufacturing smartphones.

Furthermore, the EMC Scheme introduced infrastructure interventions focussed on promoting electronics and semiconductor manufacturing. The central government, through a federal mode of implementation, provides financial assistance to state governments for setting up of EMCs and common facility centres (CFCs) across the country. Within this scheme, the Government is in the process to establish 23 EMCs and three CFCs across the country in sub-segments such as mobile phones, PCBs, consumer electronics, medical electronics, solar cell and modules, electronic components and automotive electronics across 16 states.[83] The EMCs are also acting as anchors for encouraging state-level facilitation of electronics manufacturing in India.

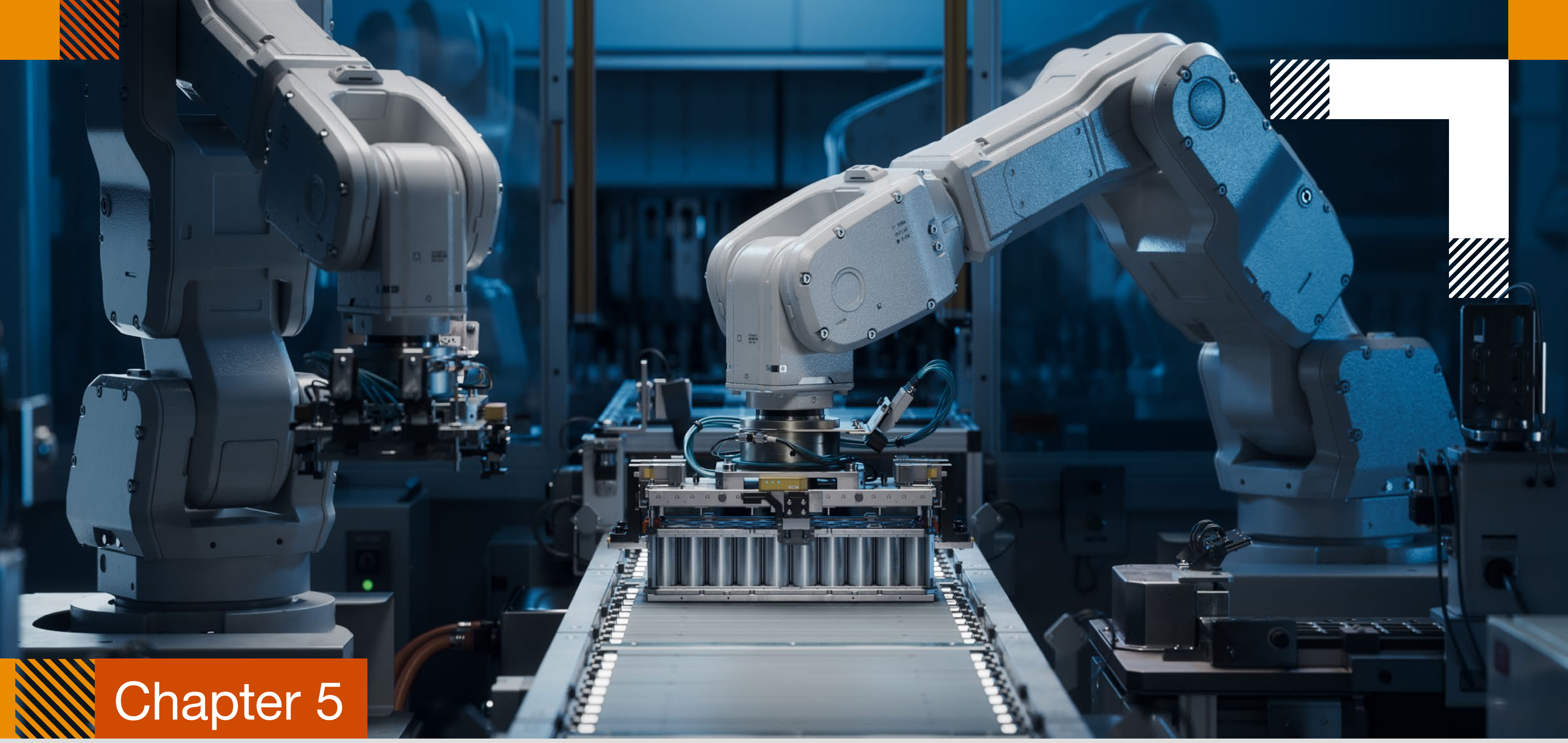
83 https://www.meity.gov.in/content/electronic-manufacturing-clusters-emc-0

## State-level interventions – addressing niche challenges and new opportunities

Furthering the anchor initiatives of the Government, several state governments have come up with complementary or supplementary initiatives to localise electronics manufacturing and the ESDM value chain in India. While legacy industrial states – such as Gujarat, Maharashtra, Tamil Nadu and Karnataka – were a few of the first movers to establish their own federal policies to emerge as competitive destinations for electronics investment in India, others such as Uttarakhand also developed their own set of customised incentives to improve their existing ecosystems of electronics and consumer appliance manufacturing. Gujarat's Semiconductor Policy 2022–27 facilitates capital subsidy (plant and machinery as well as land), exemptions of stamp duty, incentives for the availability of water, and requisite electricity duty subsidy to offset local operational challenges, making it a competitive choice for semiconductor manufacturing in India. Karnataka's Special Incentive Scheme for ESDM Sector 2020–25 adds to the Government's PLI scheme for the sector. Maharashtra's Electronics Policy 2016 facilitates state GST reimbursements while Uttar Pradesh and Telangana have been instrumental in helping with patent filing.

The culmination of these policies shows that institutions of the state governments are not merely replicating existing models but are innovating at the policy margins to cater to the needs of the industry in alignment with its localised context. For instance, Maharashtra, aware of its high degree of electronics consumption, is offering a state GST reimbursement – which would perhaps be more attractive for the manufacturer as opposed to interest subsidies. Similarly, Gujarat has a targeted subsidy for the usage of water that caters to a very specific need of the semiconductor manufacturing process, which could have emerged as an operational disability for the manufacturers. In a subsequent course of action, the Government may learn from these niche incentive structures to better enable the development of regional policies that can bridge the regional divide in electronics manufacturing and even democratise the value chain outside legacy industrial states. The template of these states can also act as policy lighthouses for others to emulate, and not just replicate, thus addressing niche ecosystem challenges and becoming competitive locations for ESDM and electronics manufacturing in India. Additionally, in the long run, this may help to reduce regional disparities between states.

With India trying to achieve the Government's target to increase its electronics manufacturing capacity to INR 24 lakh crore by 2025–26 and create over 10 lakh jobs, it is necessary for the country to come up with innovative ideas to ensure growth. Moreover, on the macro front, India has upped its game in the geopolitics arena and signed various bilateral agreements for the electronics sector in the segment of critical minerals, components procurement and technology transfers. One of the spaces where India can leverage the advantages of the electronics sector is by investing in the fabless foundry model like its East-Asian peers. For example, Taiwan's fabless foundry model has helped the country increase its global semiconductor value chain across the world. With semiconductor ubiquity in electronics, something similar can be employed by India as well. Alliances like the Chip 4 Alliance can be taken up in the domain of semiconductors. These, coupled with the structured bridge innovations at the federal level, will go a long way in strengthening India's ecosystem by addressing macro as well as micro ecosystem challenges.



Chapter 5

# Recommendations

When it comes to the development of the ESDM sector of the country, India is at a crossroads where, on the one hand, the country is trying to fix the issues related to supply and, on the other, it is trying to overcome the challenges related to establishing itself as a manufacturing leader globally.

India is regarded as a software hub and IT services trade accounts for nearly half of its total exports. IT services exports were at USD 99 billion in 2022 from USD 58.25 billion in 2018 according to the International Trade Centre's trade map data.[84] The country has built a sound services ecosystem in the digital sector without the requisite manufacturing capabilities. Therefore, India needs to strategically address both demand-side and supply-side inconsistencies to ensure that the digital economy, built on sound manufacturing and services capabilities, is resilient to future shocks.

There are several means to address the components as well as the critical raw materials issue and boost the overall ESDM manufacturing ecosystem in India. These can be broadly divided into near-term and long-term policy recommendations.

## Near-term policy actions

Near-term policy actions aim to address either urgent supply chain vulnerabilities or low hanging fruits which can be easily addressed by immediate policy action. The following are specific policies that the government can adopt in the short term to enable better GVC integration for India in the ESDM sector.

**Taxation reform:** Several key policy actions are required to smoothen the movement of components across value chains. Given the complexity of GVCs and the number of times goods cross borders before the creation of a final product, specific rules must be made for temporary storage and delivery of components. Reducing the burden of taxation for these temporary movements will make India a more cost competitive destination. Similarly, reduced rates could be considered for lead firms which need specific components from their own service companies overseas to manufacture in the country. Currently, India's permanent establishment (PE) laws are at variance with laws in other source markets such as China and Vietnam and this needs to be

84 https://www.trademap.org/Country_SelServiceCountry_TS.aspx?nvpm=1%7c699%7c%7c%7c%7c%7c%7cS09%7c1%7c3%7c1%7c2%7c2%7c1%7c2%7c1%7c%7c1

addressed to increase competitiveness. A more complex issue is that of foreign ownership of capital equipment. The existing rules of taxation do not account for foreign owned capital equipment used by OEM and component manufacturers who are making their products in India, whether on their own or by collaborating with Indian SMEs and manufacturers. The tax implications for this must be clarified.

**Tariff structures:** India currently has one of the most complex tariff structures with multiple tariff slabs for several sub-assemblies and components. High tariffs hinder competitiveness, large-scale manufacturing, and exports from India. Since 2016, India has been increasing tariffs on sub-assemblies and components whereas China and Vietnam have been reducing their tariffs consistently. This means that Vietnam and China have lower bill of materials (BoM) costs by approximately 8–10% when compared to India.[85] This is one of the major cost disabilities which needs to be addressed to attract and build GVCs, especially due to a lack of local component ecosystem. Thus, to resolve interpretation issues, litigation, retrospective increase in costs of manufacturing a smartphone, the Government must focus on complete rationalisation of tariffs. Further, there must be a glide path for inputs to smartphones towards 0 by FY 2026–27.

**IP partnerships:** Establishing stable IP partnerships for components manufacturing of existing parts is key. This cannot be achieved through offsetting manufacturing costs through PLI's or even design-led incentives for logic-chip manufacturing. Instead of attempting to re-invent the wheel, encouraging IP partnerships between IP owners and manufacturers in India is an important factor that must be addressed. This is also crucial to gain access to efficient extraction and processing technologies for critical raw materials.

**Infrastructural gaps:** India has already taken steps to address the industrial infrastructure gap through the NIP to reduce freight costs and clearance times. This momentum must be kept up. It is also important to acknowledge the importance of land, clean power, clean water, renewable energy options, and gas infrastructure at competitive rates; in addition to boosting the logistics sector of the country.

**Cross-border trade:** Addressing licensing and other non-tariff issues based on trade facilitation commitments at the World Trade Organisation (WTO) will be an important factor in the near term. Non-tariff barriers (NTBs) can be a significant cost to manufacturing. Paperless trading infrastructure and system upgrades in the next five years will be an important factor here.

**Critical raw materials resources:** In the case of critical raw materials, the vulnerability is due not only to the lack of technological capacity but also limited resource endowments. Identifying partners who have these endowments and forming mutually favourable trade and investment partnerships will be key in this segment. India must be mindful of the fact that some countries with significant deposits of critical minerals are also those where resource trade is sensitive. There must be clarity in our foreign policy and international trade policy approach towards these countries so that the trade is a mutually beneficial prospect. Treading the politics versus economics gap through 'aid for trade' and development finance rather than extractive policies would be essential.

**Developing sound international trade relationships:** Solidifying existing partnerships is another important element for near term consideration. FTAs such as the India-ASEAN and the India-MERCOSUR can be easily upgraded for mutual benefit of the participating countries. It is in the interest of all parties to build closer ties with trusted partners in strategic sectors such as ESDM given the implications for the digital economy and green transitions.

**Reducing dependency on major international suppliers:** Though it is not a long-term solution, the China +1 strategy can be considered. Even as we take steps to strengthen partnerships with amicable partner countries who are mutually interested in securing supply chains, the best solution in the short term is to continue to allow a part of imports from Chinese manufacturers, and finding solutions that make the same component sourced from a different partner more cost competitive so that dependence can reduce over time. In this sense, creating domestic champions in partnership with lead firms is important. A lead firm bringing its manufacturing facilities to India would also need local partners to provide intermediate goods. Some of these goods may already be in production domestically but not to the

85 https://icea.org.in/blog/wp-content/uploads/2024/01/Tariff-Report-3.0-1.pdf

scale or quality required. The government would have to work together with the firms to gauge their needs and build capacities.

**Implementing new policies:** An important thing to consider is what comes after the PLI schemes. While the PLIs may do the initial job of attracting lead firms to India, policies must be put in place to ensure that they stay in the long term. The scheme addresses the original disability India faces as compared to other manufacturing markets like China and Vietnam. Furthering this scheme to include new and emerging segments of the ESDM sector like component sub-assemblies will be key. The policy interventions in the next section discuss some of these methods.

## Long-term policy actions

Long-term policy actions aim to ensure that the supply of critical electronics products, components and raw materials is not disrupted. Let us look at how long-term policy interventions can help enhance India's role in the global supply chain:

1. Innovations in the ESDM sector also impact the defence sector and, therefore, can help in enhancing the strategic autonomy of India. The country should actively increase its investment in dual use technologies and R&D. Incentivising public private partnerships in this sector and how they play out in the next ten to fifteen years will be a decisive factor for strategic national security.

2. It needs to be noted that new product prototypes that are developed for future sale require several inputs that have to be imported from various economies. Only a handful of these are ultimately used in the assembly of the final prototype. With the process involving multiple stakeholders including the brand, engineering teams, testing labs, factories, etc., the inputs constantly change ownership and location – in and out of the Manufacturing and Other Operations in Customs Bonded Warehouse (MOOWR) zones and sometimes even exported for international testing. Such movements from one location to another (within the country or even outside the country) come with tax implications for those importing components for R&D and assembly – multiple taxing without understanding the purpose can add to the cost of doing business in India, thereby making the economy less competitive as compared to other competing economies like China or Vietnam. Addressing this challenge demands a strategic approach. Proposing a tax exemption for inputs specifically earmarked for R&D and prototype development, irrespective of ownership or location, can effectively streamline operations. This exemption, contingent upon a transparent declaration by sourcing organisations confirming the non-commercial nature of both the components and their prototypes, coupled with third-party audits, ensures accountability and compliance. However, what India needs to do at this stage is to create a tailored, best-in-class taxation framework that will be competitive and comparable to those offered in international locations like China and Vietnam, for product development and related R&D activities. Such a framework, characterised by its efficacy and comparability, promises to mitigate transaction costs, incentivise R&D endeavours, and elevate India's standing in the global business landscape, particularly within the realm of product development and associated innovation.

3. Another important area which needs to be considered is the development of a large talent pool of skilled employees. Skill development is imperative for three reasons:

    i) Creation of new jobs for a growing population and bridging the pay gap in the manufacturing sector will also create demand-side stability for the sector.

    ii) The ESDM sector shows the most potential for continued expansion. Even as redundancies creep into old technology, making sure that current and future workers in this sector are constantly trained and upgrading their skills needs to be a conscious part of policy decisions.

    iii) Skilled human resources are a competitive cost factor for India and will continue to be so for the near future. Investing in our demographic dividend also has social benefits. Considered collaboration between relevant ministries through policies like Skill India and an analysis of the efficacy of this policy is necessary.

4. Support infrastructure around factories can also be developed to ensure basic facilities like housing are available for the expected new workers. This would contribute towards worker welfare and also encourage more women to join if safe housing and other community facilities and infrastructure are available. Policies to ensure the development of this infrastructure will also help in creating new job opportunities as schools, hospitals, and other basic facilities come up in these areas. Flexible labour rules and full implementation of the Labour Code on Occupational Safety, Health and Working Conditions, 2020, will also be beneficial.

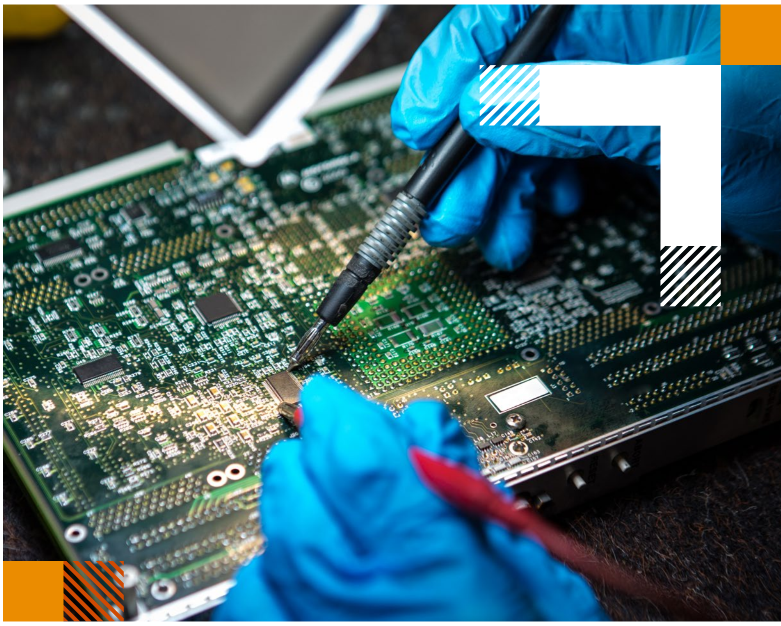
5. India needs to adopt a cautious approach while collaborating with new partner countries. Whether these partnerships take the form of investment treaties or trade agreements can be determined based on the part of the value chain vulnerability they are addressing. The main interest from the Global North is more technology transfer and therefore more investments. The Global South, wants to not only to encourage investment from India into these regions, but also import cost-effective components even as they build their manufacturing capacity. A true analysis of the sectoral ask from each region based on the ten-year trade potential must be mapped to get ahead.

6. As state-level policies are beneficial in giving an impetus to further growth in the sector, similar policy interventions that can be replicated in other states should be encouraged by the Centre through its coordinating agencies. For instance, the Ministry of Commerce could work with state-level commerce ministries to assess the capacity of the states with effective policies and encourage non-performing states to implement policies that suit their region, thus moving towards cooperative rather than competitive federalism.

7. Geopolitical risks and external shocks will continue to play a role in trade policy regardless of internal efforts. India must carefully choose its partners for the next ten years. These will be partners who will grow together and build better bonds in the region for a cohesive development journey

8. Regulators should expand the basket of critical minerals to be traded in Indian commodity exchanges. It is also up to the commodities exchanges or ‘commexes’ to have proper price settlement mechanisms so that the cash-settled or compulsory delivery-based contracts reflect on the global fundamentals and result in efficient price discovery and hedging efficiency. This move can address the significant supply-demand imbalance by attracting investments and encouraging the development of a more robust domestic mining infrastructure. Such an initiative would significantly bolster supply chain resilience, ensuring a more stable and predictable supply of critical minerals in India.

To conclude, one can say that India is comfortably placed as a dependable partner in the global manufacturing market. The country must now leverage this momentum to ensure that its internal goals enable it to become future-ready. A multi-pronged ecosystem approach is essential to ensure that the centre of the ESDM sector in India holds firm.



# Notes

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